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GÖTEBORGS KUNGL. VETENSKAPS- OCH VITTERHETS-SAMHÄLLE

REPORTS OF THE SWEDISH DEEP-SEA EXPEDITION 1947—1948

EDITED BY
HANS PETTERSSON
SCIENTIFIC LEADER OF THE EXPEDITION

VOLUME VI

Sediment Cores from the West Pacific

FASC. III

GÖTEBORG
ELANDERS BOKTRYCKERI AKTIEBOLAG

REPORTS OF THE SWEDISH DEEP-SEA EXPEDITION. VOL. VI
SEDIMENT CORES FROM THE WEST PACIFIC NO. 3

RADIOLARIA

A PRELIMINARY STRATIGRAPHY

BY

WILLIAM R. RIEDEL

SCRIPPS INSTITUTION OF OCEANOGRAPHY
LA JOLLA, CALIFORNIA

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Introduction

EHRENBERG (1861 a, 1861 b, 1872, 1873) described a few Radiolaria from near the Philippine Is. and between California and Hawaii, but the accumulation of knowledge of the Radiolaria of the Pacific Ocean may be said to have begun and ended with the monumental monograph prepared by HAECKEL (1887) on the Radiolaria collected by the »Challenger» expedition of 1873—76. Before and since the cruise of the »Challenger», radiolarian investigations on a smaller scale were carried out in the Atlantic and Indian Oceans, while the Pacific was almost completely neglected. HAECKEL's »Challenger» monograph comprises descriptions of Radiolaria from plankton and sediment samples collected throughout the cruise, and a large proportion of the species described were from the Pacific. The result of his work was that a great number of species were known to occur in the Pacific, but he rarely gave any indication of the distribution of the forms observed. Although he may have observed certain species in many samples from both surface and sediment samples, he often included only one or a few localities in his descriptions, because for the preparation of full locality lists »the necessary accurate determination and identification of the species . . . . . would have occupied too much time.» Also, he often gives no indication whether his recorded occurrences are from surface or bottom samples. Thus his monograph is of immense importance taxonomically, but it contains little of zoogeographical or geological significance.

The large number of long sediment cores, collected by the Swedish Deep-Sea Expedition with the revolutionary corer developed by Dr. BÖRJE KULLENBERG, offers an opportunity for the study of the Radiolaria of the tropical Pacific of the present day, and the development of the fauna through the Quaternary and part of the Tertiary. When Dr. HANS PETTERSSON, leader of the Swedish Deep-Sea Expedition and director of the Oceanografiska Institut, made samples from the western Pacific cores available to the author for study of the Radiolaria, it was expected that the assemblages in the tops of the cores could be used to determine the areal distribution of various species at the present day, while samples from lower levels of the cores would show, in an orderly manner, the development of present-day species through at least Pleistocene and Recent time.

Preliminary work on the cores (RIEDEL, 1952) indicated, however, that the situation is actually

more complicated than was expected. Late Tertiary Radiolaria were found to be reworked into Recent sediments, and evidence of disconformities was found in the sediment sequences. Re-examination of some of the samples from the »Challenger» expedition of 1873—76 showed that Tertiary sediments outcrop on the deep-sea floor (e. g., RIEDEL, 1954). Erosion, and reworking of older Radiolaria into younger sediments, obscure phylogenetic developmental sequences in the long sediment cores.

It is, therefore, of primary importance to determine the ages of the sediment at various levels in the cores, to recognize interruptions in the sequences, and to detect and date older forms reworked into younger levels. Many of the cores contain no other microfossils which can be used for age-determination, and therefore the Radiolaria themselves must be used for this purpose. Before these investigations were begun on the material from the Deep-Sea Expedition, Radiolaria had not been used for the determination of ages of Tertiary and Quaternary sediments, and therefore much preliminary research on Tertiary radiolarian assemblages of known ages had to be done in order to determine the stratigraphic ranges of various species, and to select those which are likely to be good age-indicators. Because the stratigraphy of the Tertiary and Quaternary Radiolaria is such a new study, with no large body of published information on which it can be based, age-determinations on the basis of radiolarian assemblages must necessarily be tentative at present.

This first phase of the investigation of the Radiolaria of the western Pacific sediment cores is restricted in scope, being concerned primarily with the general stratigraphy of the sediments. Where necessary, attempts have been made to clarify problems of the taxonomy of species used as age-indicators, in order that these may be well-defined. The geographical distributions of present-day species have not been studied in detail, but it was found at an early stage of the investigation (RIEDEL, 1951, 1952) that many of the common species of the tropical waters are widely distributed in the Pacific and Indian oceans, indicating that the radiolarian fauna of the low latitudes is relatively homogeneous.

On the basis of the general stratigraphy as developed in this report, future work on the Radiolaria of the cores will be concentrated on the phylogenetic development of the tropical Pacific species: it is hoped that this will lead to the possibility of formulating a revised classification of the Radiolaria which will more closely approach a natural system than does HAECKEL's.

For the opportunity to carry out this study, the author is greatly indebted to Dr. HANS PETTERSSON, who made it possible for the author to spend more than a year in Göteborg, and placed the sediment samples at his disposal. Subsequently, facilities to continue the investigation were made available by Scripps Institution of Oceanography, in California, and the South Australian Museum, Adelaide. At Scripps Institution, the study was carried out under contract with the U.S. Office of Naval Research. Additional financial support was generously provided by Göteborg's Sjöfartsmuseum, and the Royal Society committee for the John Murray Travelling Studentship in Oceanography and Limnology. Numerous paleontologists and geological institutions have greatly facilitated this work by supplying Tertiary radiolarian samples for comparison with the Pacific forms. The authorities of the British Museum (Natural History), through Dr. J. D. H. WISEMAN, have made available small samples of the invaluable original »Challenger» material, in order that some of the species described by HAECKEL might be re-examined from their type localities. For valued advice during the progress of this investigation, the author is indebted to Dr. M. N. BRAMLETTE, and to Dr. CARL L. HUBBS who has given assistance on nomenclatural problems.

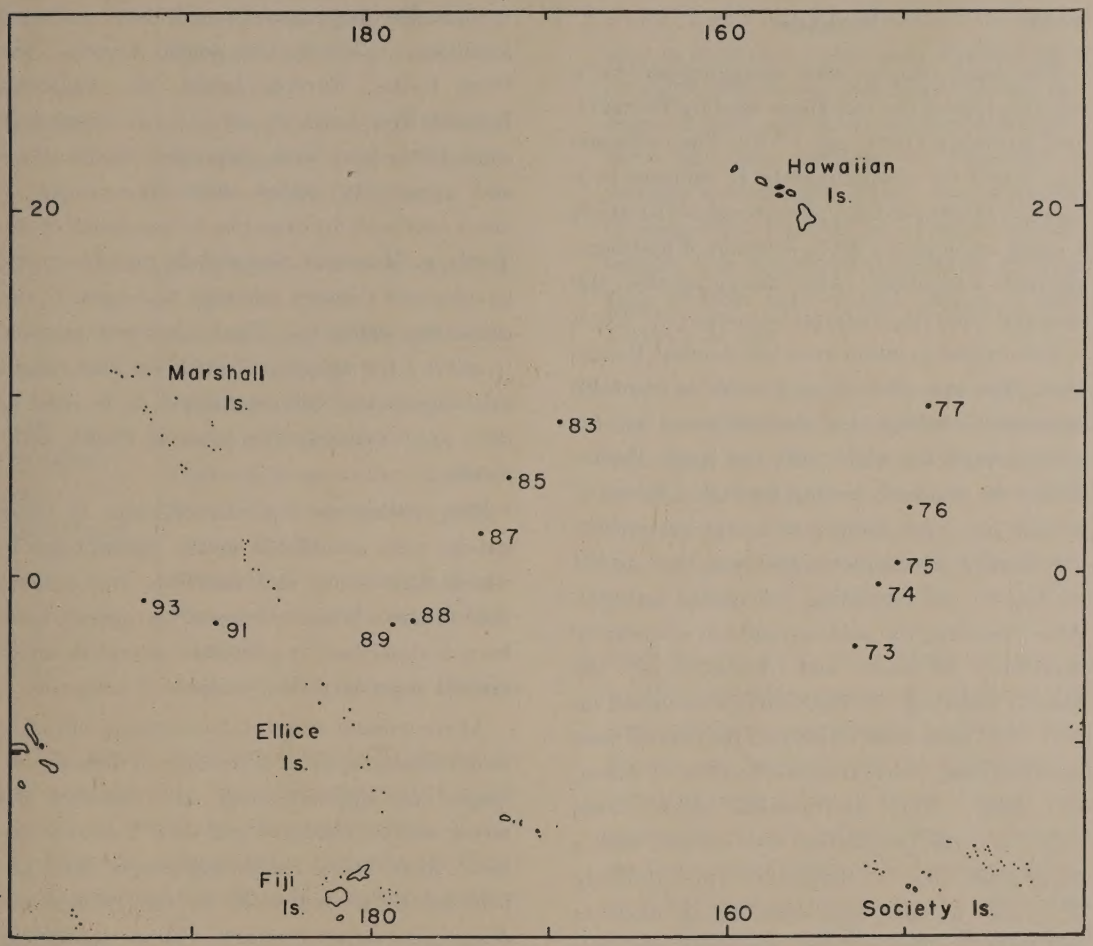

Figure 1. Locations of the cores examined.

Material studied

Twelve piston cores from the western Pacific (Fig. 1) were sampled, usually at intervals of approximately 1 metre, but at varying intervals if the lithology indicated that this was desirable. As it is probable that at least some centimetres of sediment are lost from the tops of the long cores, short gravity cores were taken at the same time as the long cores in order to be sure of obtaining the uppermost layer. Four of these short supplementary cores (indicated by »B» numbers) were examined in conjunction with the long cores.

The cores embraced in this study are the following:

Core no.	*Geographic position*	*Depth (m.)*	*Section of core examined (cm.)*	*Number of samples*
73 B	S 04° 04′ W 152° 53′	5200	10 — 49	4
73	S 04° 04′ W 152° 53′	5200	11.5 —1471	18
74	S 00° 29′ W 151° 33′	4575	1 —1340	15
75	N 00° 20′ W 150° 36′	4400	9 — 820	9
76 B	N 03° 45′ W 149° 44′	5155	10 — 25.5	3
76	N 03° 45′ W 149° 44′	5155	7.5 —1330	14
77 B	N 09° 30′ W 148° 40′	5384	6.25— 26	2
77	N 09° 30′ W 148° 40′	5384	9 —1310	8
83	N 08° 40′ W 169° 28′	5456	1 — 290	4
85 B	N 05° 34′ W 172° 12′	5590	1 — 79.5	7
85	N 05° 34′ W 172° 12′	5590	29 —1050	13
87	N 02° 23′ W 173° 50′	5560	0 — 900	17
88	S 02° 37′ W 177° 45′	5770	6 — 173	18
89	S 02° 48′ W 178° 57′	5465	0 — 900	10
91	S 02° 50′ E 171° 18′	4096	26 —1410	15
93	S 01° 20′ E 167° 23′	3942	0.5 —1509	16

Methods

The dried samples were disaggregated by a modification of the technique used by FRIZZELL and MIDDOUR (1951, pp. 4—5). The sediment was boiled for approximately 15 minutes in a solution of tetra sodium pyrophosphate to which a small amount of a 30 % solution of hydrogen peroxide was added. After disaggregation, the clay and other fine material was removed. When it was desired to retain even the smallest Radiolaria, this was effected by a series of carefully controlled settlings and decantations, but for routine work for which only the larger Radiolaria were required, sieving through a screen of 62 μ or 74 μ mesh opening was most convenient.

Sufficient hydrochloric acid was then added to dissolve all remaining calcareous material. After removing the acid and salts in solution by successive dilutions and decantations, the residue including the Radiolaria was spread on a 3″ × 1″ glass slide which had previously been smeared thinly with albumen fixative or saliva, and dried. Xylol and canada balsam were added and the preparation was covered with a cover-glass (no. 1 thickness) approximately 2″ × 3/4″ in size, and dried in an oven at 50—60° C. Strewn-slides prepared by this method were found to be most satisfactory for the routine examination of samples. Throughout the preparation, every possible precaution was taken to prevent contamination by keeping sieves and pipettes scrupulously clean.

Illustrations for the plates have all been made with the aid of a camera lucida, and reduced to approximately a half of their original size during reproduction. Type and figured specimens will be placed in the collections of the U. S. National Museum, Washington, D. C.

Species used as Age-Indicators

In order to determine which species occuring in the tropical Pacific sediments are most useful for age determinations, the author has examined a large number of radiolarian assemblages of various Tertiary ages from widely scattered localities — North and South America, the West Indies, Europe, Israel, the Andaman Islands, New Zealand, etc. It was found that some forms have wide geographic distributions and apparently rather short time-ranges — often confined, for example, to one epoch of the Tertiary. Moreover, many of the forms occuring in subaerial Tertiary outcrops also occur in the submarine sediments. Thus it has been possible to select a few species, of which the time-ranges are more or less well established, to be used to date approximately the tropical Pacific sediments.

The criteria used in the selection of these species were abundance in the assemblages in which they occur, and relatively well-defined time-ranges. When necessary, the species have been re-described to give more complete information regarding their ranges of variation.

At the present stage of development of radiolarian stratigraphy, it is possible to date assemblages only approximately, and therefore the terms »early», »middle» and »late Tertiary» are used. Assemblages containing species which are believed to be restricted to the Eocene are designated »early Tertiary». Those containing species which are apparently restricted to the Oligocene and lowest Miocene are designated »middle Tertiary». The general term »late Tertiary and Quaternary» is used to embrace the period of time from approximately middle Miocene to Recent.

The species used as indicators of various ages are the following:

Early Tertiary	*Eusyringium fistuligerum* (Ehrenberg)
	Calocyclas turris Ehrenberg
	Sethamphora mongolfieri (Ehrenberg)
	Phormocyrtis embolum (Ehrenberg)
	Dictyophimus babylonis Clark and Campbell

Middle Tertiary	*Calocyclas virginis* Haeckel *Tympanidium binoctonum* Haeckel *Dipodospyris forcipata* Haeckel *Dorcadospyris dentata* Haeckel *Stichocorys wolffii* Haeckel
Late Tertiary and Quaternary	*Eucyrtidium delmontense* Campbell and Clark *Anthocyrtium ehrenbergii ehrenbergii* (Stöhr) *?Anthocyrtium ehrenbergii pliocenica* (Seguenza) *Lychnodictyum audax* Riedel *Eucyrtidium elongatum peregrinum* Riedel *Pterocanium prismatium* n. sp. *Pterocanium praetextum* (Ehrenberg) *Anthocyrtidium cineraria* Haeckel

Two species for which there are at present no independent data as to time-range, but which are found useful for the confirmation of late Tertiary age assignments in the cores are *Panarium penultimum* n. sp. and *Acrobotrys tritubus* n. sp.

A factor which may tend to lead to errors in interpretation in the stratigraphy of deep-sea cores is that early and middle Tertiary Radioalaria apparently had generally heavier skeletons than late Tertiary and Quaternary forms. This appears to be the case in the few known Tertiary assemblages in which all of the species seem to have been preserved. Thus if a mixture of Quaternary and middle Tertiary Radiolaria were subjected to a certain degree of dissolution, it is possible that only the older species would remain recognizable. This factor of uncertainty has been taken into account in the interpretation of the radiolarian assemblages of the western Pacific cores: samples in which only badly dissolved Tertiary forms were found are not regarded as necessarily being older than Quaternary.

Early Tertiary. — Most of the species used as indicators of the early Tertiary occur in widely-separated, well-dated Eocene outcrops on land, and many of them apparently have no close relatives in Oligocene or younger assemblages. Thus, when a number of them occur together in a Pacific sediment sample, this is considered sufficient evidence that at least part of that sample is early Tertiary in age.

Middle Tertiary. — Very few Oligocene and lower Miocene radiolarian assemblages have been described, and the determination of species useful as indicators of middle Tertiary age is based primarily on examination of undescribed assemblages from the West Indies.

Late Tertiary and Quaternary. — A considerable number of well-dated Miocene radiolarian assemblages are known from Europe and America, and the upper parts of sediment cores taken in areas of rapid sedimentation provide reliable data for some of the Quaternary forms: it is therefore possible to select species which can be used with some degree of confidence as indicators of »late Tertiary or Quaternary».

It also appears that the Radiolaria can be used, at least in the western Pacific, to subdivide this »late Tertiary and Quaternary» period into three parts.

The lower sections of two eastern Pacific cores (nos. 58 and 62) which ARRHENIUS (1952) considers to penetrate into the Pliocene contain a distinctive species, *Pterocanium prismatium* n. sp., which does not occur in younger sediments. In several of the western Pacific cores, this species is associated with another distinctive form, *Eucyrtidium elongatum peregrinum* Riedel, which was first described from a sediment of probably very late Tertiary age. The upper limits of common occurrence of these two forms in the western Pacific cores appear to be

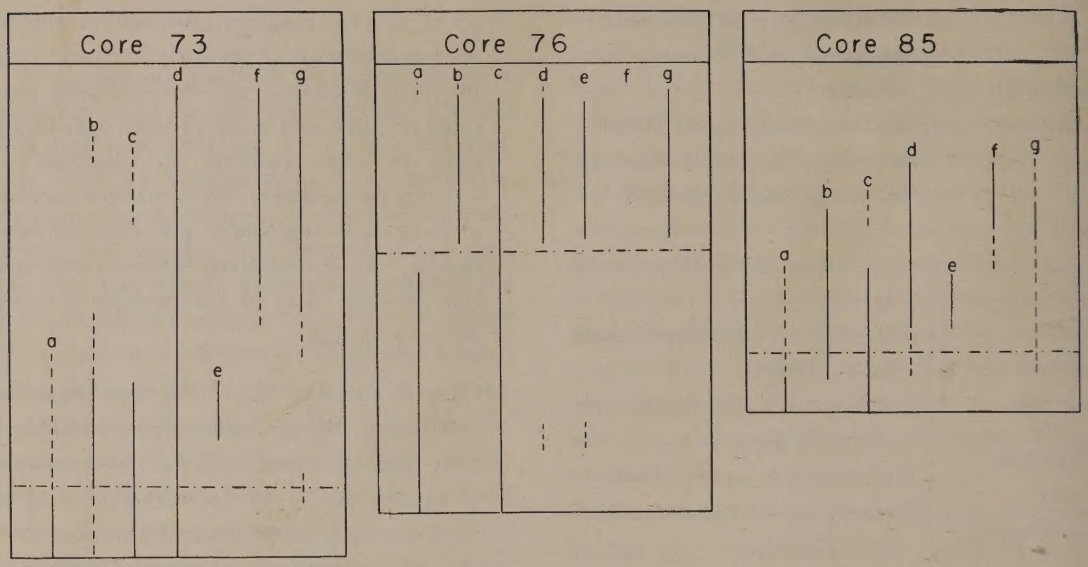

Figure 2. Diagram to illustrate the ranges of seven species on either side of the level regarded as the approximate »Miocene-Pliocene boundary» (dot-dash line). a, *Eucyrtidium delmontense;* b, *Panarium penultimum;* c, *Lychnodictyum audax;* d, *Eucyrtidium elongatum peregrinum;* e, *Acrobotrys tritubus;* f, *Pterocanium prismatium;* g, *Anthocyrtidium cineraria.* Solid lines indicate major zones of occurrence, and broken lines relatively rare or sporadic occurrence.

approximately synchronous, and may be regarded tentatively as representing the »top of Pliocene» — the phrase being placed in quotation marks to emphasize its somewhat inexact use.

The sediment above the upper limit of common *Pterocanium prismatium* and *Eucyrtidium elongatum peregrinum* is thus tentatively regarded as »Quaternary».

Another level which is found to be rather sharply marked in several Pacific sediment cores is the upper limit of common *Eucyrtidium delmontense* Campbell and Clark. This species, and forms closely resembling it, are abundant and widespread in Miocene sediments, and for our present purposes the upper limit of its common occurrence may be tentatively termed the »top of the Miocene». The ranges of several other species about this level in three sediment cores (Fig. 2) appear to support the contention that it is synchronous in different cores.

R e w o r k i n g. — Many radiolarian species, which on the basis of their occurrence in some dated subaerial Tertiary outcrops appear to be restricted to the earlier Tertiary epochs, are found mixed in tropical Pacific sediments with forms having apparently later time-ranges. The question then arises, whether the older forms persisted longer than indicated by their occurrence in well-dated sediments, or whether submarine erosion and transport has resulted in the reworking of older species into younger sediments.

It appears that reworking has taken place in many instances. If the upper parts of two cores taken in the relatively uniform central Pacific differ in that only one contains Radiolaria which (on the basis of other occurrences) appear to have been restricted to an early Tertiary epoch mixed with forms known to be Recent, it is unlikely that persistence of the older forms has accounted for this anomaly. In the interpretation of the western Pacific cores, the occurrence of several apparently older forms occurring together, mixed with an apparently younger assemblage, is interpreted as evidence of reworking. Although the time-ranges of some of the indicator-species may very probably be modified as the result of later investigations, it

CORE NO. 73 B

Depth below surface of core (cm.)	Early Tertiary					Middle Tertiary					Late Tertiary and Quaternary									
	Eusyringium fistuligerum	*Calocyclas turris*	*Sethamphora mongolfieri*	*Phormocyrtis embolum*	*Dictyophimus babylonis*	*Calocyclas virginis*	*Tympanidium binoctonum*	*Dipodospyris forcipata*	*Dorcadospyris dentata*	*Stichocorys wolffii*	*Eucyrtidium delmontense*	*Panarium penultimum*	*Anthocyrtium ehrenbergii ehrenbergii*	*?Anthocyrtium ehrenbergii pliocenica*	*Lychnodictyum audax*	*Eucyrtidium elongatum peregrinum*	*Acrobotrys tribulus*	*Pterocanium prismatium*	*Pterocanium praetextum*	*Anthocyrtidium cineraria*
10—11	—	—	r	r	r	r	r	r	r	r	r	r	—	—	r	r	—	r	c	c
23—24	—	—	r	r	r	c	r	r	—	r	—	r	r	—	r	r	—	r	c	c
38—39	—	—	r	r	r	c	r	r	—	r	r	r	—	—	—	c	—	—	c	c
48—49	—	—	r	r	r	c	c	r	c	c	—	—	—	—	—	r	—	—	—	—

appears possible now to detect admixture of early Tertiary or middle Tertiary forms with late Tertiary or Quaternary assemblages.

Distribution of Indicator-Species in the Cores

In the following tables, the occurrences of species are indicated as abundant (a), common (c) or rare (r), in relation to the entire radiolarian assemblage of the sample. Where the number of tests found was insufficient to determine relative abundance, presence is indicated by +. Doubtful identifications are indicated by ?.

CORE NO. 73 B.

The top three samples examined from this core contain abundant well-preserved Radiolaria, but those of the fourth sample show marked signs of solution — despite the fact that throughout the long core no. 73 no such

CORE NO. 73

Depth below surface of core (cm.)	Early Tertiary					Middle Tertiary					Late Tertiary and Quaternary									
	Eusyringium fistuligerum	*Calocyclas turris*	*Sethamphora mongolfieri*	*Phormocyrtis embolum*	*Dictyophimus babylonis*	*Calocyclas virginis*	*Tympanidium binoctonum*	*Dipodospyris forcipata*	*Dorcadospyris dentata*	*Stichocorys wolffii*	*Eucyrtidium delmontense*	*Panarium penultimum*	*Anthocyrtium ehrenbergii ehrenbergii*	*?Anthocyrtium ehrenbergii pliocenica*	*Lychnodictyum audax*	*Eucyrtidium elongatum peregrinum*	*Acrobotrys tribulus*	*Pterocanium prismatium*	*Pterocanium praetextum*	*Anthocyrtidium cineraria*
11.5—12.5	—	—	r	r	—	r	r	—	r	—	—	—	—	—	—	a	—	a	r	c
49—50	—	—	r	r	r	r	r	—	r	r	—	—	—	—	—	a	—	c	r	r
111.5—112.5	—	—	—	r	—	r	r	—	r	r	—	—	—	—	—	a	—	a	r	c
149—150	—	—	r	r	—	r	r	r	r	r	—	—	—	—	—	a	—	a	—	c
211.5—212.5	—	—	—	—	—	r	r	r	r	r	—	r	—	—	r	a	—	a	r	c
249—250	—	—	—	—	—	r	r	r	r	—	—	—	—	—	—	a	—	c	r	c
349—350	—	—	—	r	—	r	r	—	—	r	—	—	—	—	r	a	—	c	—	c
449—450	—	—	—	—	—	r	r	r	—	—	—	—	—	—	r	a	—	c	r	c
549—550	—	—	r	—	—	r	r	—	r	r	—	—	—	—	—	a	—	c	—	c
649—650	—	—	—	r	—	r	—	r	—	r	—	—	—	—	—	a	—	c	—	c
749—750	—	—	—	r	—	r	r	r	r	r	—	r	—	—	—	a	—	r	—	c
847—848	—	—	—	r	—	r	r	r	—	r	r	r	—	—	—	a	—	—	—	r
949—950	r	—	r	r	—	r	r	—	—	r	r	c	—	—	r	a[1]	r	r	—	—
1049—1050	—	—	r	—	—	r	r	r	—	r	r	c	—	r	r	a	r	—	—	—
1111.5—1112.5	—	—	—	—	—	r	r	r	r	—	r	c	r	c	r	a	r	—	—	—
1249—1250	—	—	—	—	—	r	r	—	—	r	r	c	—	c	r	a	—	—	—	r
1349—1350	—	—	r	—	—	r	r	—	r	r	c	r	—	c	r	a	—	—	—	
1470—1471	—	—	—	r	—	r	r	r	r	r	c	r	—	c	r	a	—	—	—	—

[1]) In this sample, and the five samples below it (to the bottom of the core), specimens of *Eucyrtidium elongatum peregrinum* show a tendency to have the third segment inflated rather than conical, and broader than the fourth segment: thus they approach *Eucyrtidium delmontense*.

CORE NO. 74

Depth below surface of core (cm.)	Early Tertiary					Middle Tertiary					Late Tertiary and Quaternary									
	Eusyringium fistuligerum	*Calocyclas turris*	*Sethamphora mongolfieri*	*Phormocyrtis embolum*	*Dictyophimus babylonis*	*Calocyclas virginis*	*Tympanidium binoctonum*	*Dipodospyris forcipata*	*Dorcadospyris dentata*	*Stichocorys wolfii*	*Eucyrtidium delmontense*	*Panarium penultimum*	*Anthocyrtium ehrenbergii ehrenbergii*	*?Anthocyrtium ehrenbergii pliocenica*	*Lychnodictyum audax*	*Eucyrtidium elongatum peregrinum*	*Acrobotrys tritubus*	*Pterocanium prismatium*	*Pterocanium praetextum*	*Anthocyrtidium cineraria*
1—2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	c	c
99—100	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	c	c
199—200	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	c	c
299—300	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	c	c
399—400	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	c	c
499—500	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	c	c
599—600	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	c	c
699—700	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	c	c
799—800	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	c	c
899—900	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	c	c
999—1000	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	c	c
1099—1100	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	c	c
1189—1190	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	c	c
1279—1280	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	c	c
1339—1340	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	c	c

pronounced solution effects were observed. At depths of 10—11, 23—24, and 38—39 cm. in core 73 B, the assemblage is apparently Quaternary (above the level of common *Pterocanium prismatium* and *Eucyrtidium elongatum peregrinum*), but containing reworked lower, middle, and upper Teriary species, while the sediment at 48—49 cm. is perhaps very late Tertiary, with a much greater admixture of reworked, mostly middle Tertiary species.

CORE NO. 73

Radiolaria are well-preserved and abundant in all samples examined from this core. If the upper limit of *Pterocanium prismatium* is taken to represent approximately the top of the Tertiary, it appears that this core represents a probably uninterrupted sequence through a considerable part of the upper Tertiary. The uppermost sample (from a depth in the core of 11.5—12 cm.) is probably late Tertiary, and if any Quaternary is present it must be a very thin layer. A considerable number of middle Tertiary, and fewer lower Tertiary species, are found throughout the core.

CORE NO. 74

Radiolaria are abundant and well-preserved in all samples examined from this core. The fact that *Pterocanium praetextum* and *Anthocyrtidium cineraria* are the only indicator-species found suggests that the entire core may be Quaternary, deposited after the disappearance of *Pterocanium prismatium*.

CORE NO. 75

Well-preserved Radiolaria are abundant in all samples examined from this core, with the exception of a sample from 209.5—210 cm., where very few radiolarian tests were found (insufficient for an age-determination). This sample is a foraminiferal sand, while those from the other levels are fine-grained oozes consisting largely of coccoliths and small diatoms: thus the sample from 209.5—210 cm. was apparently subjected to current winnowing, which removed almost all of the Radiolaria together with the finer constituents. Throughout the core, no indications of lower or middle Tertiary species were found, and it appears probable that the entire column is Quaternary.

CORE NO. 75

Depth below surface of core (cm.)	Early Tertiary					Middle Tertiary					Late Tertiary and Quaternary									
	Eusyringium fistuligerum	*Calocyclas turris*	*Sethamphora mongolfieri*	*Phormocyrtis embolum*	*Dictyophimus babylonis*	*Calocyclas virginis*	*Tympanidium binoctonum*	*Dipodospyris forcipata*	*Dorcadospyris dentata*	*Stichocorys wolfii*	*Eucyrtidium delmontense*	*Panarium penultimum*	*Anthocyrtium ehrenbergii ehrenbergii*	*?Anthocyrtium ehrenbergii pliocenica*	*Lychnodictyum audax*	*Eucyrtidium elongatum peregrinum*	*Acrobotrys tritubus*	*Pterocanium prismatium*	*Pterocanium praetextum*	*Anthocyrtidium cineraria*
9—9.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	c	c
109.5—110	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	c	c
309.5—310	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	c	c
409.5—410	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	c	c
509.5—510	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	c	c
609.5—610	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	c	c
711.5—712	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	c	c
819.5—820	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	c	c

CORE NO. 76 B

Radiolaria are abundant and well-preserved in each of the three samples examined from this core. The top sample (10—10.5 cm.) is apparently very young, above the zone of abundant *Eucyrtidium elongatum peregrinum* and *Pterocanium prismatium*, and contains rather few reworked upper, middle, and lower Tertiary species. The samples from 20 and 25 cm. are markedly different, characterized by abundant *Eucyrtidium elongatum peregrinum*, scarcity or absence of *Pterocanium praetextum* and *P. prismatium*, and a smaller number of reworked older species. It appears that the top (less than 10 cm.) of this core may be Quaternary, resting disconformably on very late Tertiary sediment.

CORE NO. 76

Radiolaria are abundant and well-preserved in all samples examined from this core. The top sample is the only one containing common *Pterocanium praetextum*, and is probably Quaternary in age. The samples from the following 5 metres are characterized by abundant *Eucyrtidium elongatum peregrinum*, and are probably late Tertiary. Below 6 metres depth, *Eucyrtidium elongatum peregrinum* disappears and *Eucyrtidium delmontense* becomes abundant: this lower part of the core is also probably late Tertiary in age, though the appearance of more middle Tertiary forms below 12 metres may indicate that the bottom of the core approaches the Oligocene. The similarity between the assemblage in the sample from 7.5—8 cm. in Core 76 and that in the sample from 10—10.5 cm. in the short Core 76 B indicates that little or no sediment was lost from the top of the piston core, and that Core 76 also has a thin layer of probably Quaternary sediment resting disconformably on a continuous sequence of

CORE NO. 76 B

Depth below surface of core (cm.)	Early Tertiary					Middle Tertiary					Late Tertiary and Quaternary									
	Eusyringium fistuligerum	*Calocyclas turris*	*Sethamphora mongolfieri*	*Phormocyrtis embolum*	*Dictyophimus babylonis*	*Calocyclas virginis*	*Tympanidium binoctonum*	*Dipodospyris forcipata*	*Dorcadospyris dentata*	*Stichocorys wolfii*	*Eucyrtidium delmontense*	*Panarium penultimum*	*Anthocyrtium ehrenbergii ehrenbergii*	*?Anthocyrtium ehrenbergii pliocenica*	*Lychnodictyum audax*	*Eucyrtidium elongatum peregrinum*	*Acrobotrys tritubus*	*Pterocanium prismatium*	*Pterocanium praetextum*	*Anthocyrtidium cineraria*
10—10.5	r	—	—	r	r	r	r	—	—	r	r	r	—	r	r	r	r	r	c	c
20—20.5	r	—	r	—	—	r	—	—	—	r	c	c	r	c	r	a	r	r	r	r
25—25.5	—	—	—	r	—	—	—	—	—	—	—	c	r	r	r	a	—	—	—	c

CORE NO. 76

Depth below surface of core (cm.)	Early Tertiary					Middle Tertiary					Late Tertiary and Quaternary									
	Eusyringium fistuligerum	*Calocyclas turris*	*Sethamphora mongolfieri*	*Phormocyrtis embolum*	*Dictyophimus babylonis*	*Calocyclas virginis*	*Tympanidium binoctonum*	*Dipodospyris forcipata*	*Dorcadospyris dentata*	*Stichocorys wolfii*	*Eucyrtidium delmontense*	*Panarium penultimum*	*Anthocyrtium ehrenbergii ehrenbergii*	*?Anthocyrtium ehrenbergii pliocenica*	*Lychnolictyum audax*	*Eucyrtidium elongatum peregrinum*	*Acrobotrys tritubus*	*Pterocanium prismatium*	*Pterocanium praetextum*	*Anthocyrtidium cineraria*
7.5—8	—	—	r	r	—	—	—	—	—	r	r	r	—	—	—	r	—	—	c	c
108.5—109	—	—	—	—	—	—	—	—	—	—	—	c	—	r	r	a	r	—	—	c
208.5—209	—	—	—	—	r	r	—	—	—	—	—	c	—	r	r	a	r	—	—	c
308.5—309	—	—	—	—	—	r	—	—	—	—	—	c	r	r	r	a	r	—	—	c
408.5—409	—	—	—	—	—	r	—	—	—	—	—	c	—	r	r	a	r	—	—	c
509—509.5	—	—	—	—	—	—	—	—	—	—	—	c	—	r	r	a	r	—	—	c
608.5—609	—	—	—	—	—	—	—	—	—	—	a	—	—	r	r	—	—	—	—	—
708.5—709	—	—	—	—	—	—	—	—	—	—	a	—	r	c	r	—	—	—	—	—
809—810	—	—	—	—	—	—	—	—	—	—	a	—	r	c	r	—	—	—	—	—
909—910	—	—	—	—	—	—	—	—	—	—	a	—	r	c	r	—	—	—	—	—
1009—1010	—	—	—	—	—	—	—	—	—	—	a	—	r	r	c	—	—	—	—	—
1109—1110[1])	—	—	—	—	—	r	—	—	—	—	a	—	r	r	r	a	r	—	—	—
1228.5—1229	—	—	—	—	—	—	r	—	—	c	a	—	r	—	r	—	—	—	—	—
1329—1330	—	—	—	—	—	r	r	—	—	r	a	—	r	c	r	—	—	—	—	—

[1]) The sample from this level which was submitted to the author is somewhat enigmatic. It consisted of two parts having quite distinct colours — one greyish, and the other creamy white. In the greyish portion, the three indicator-species of *Anthocyrtium* and *Anthocyrtidium* were absent or rare, *Eucyrtidium elongatum peregrinum* was absent, and *Eucyrtidium delmontense* abundant:thus this portion apparently fits well into the sequence. In the creamy white portion, *Anthocyrtidium elongatum peregrinum* was abundant, *?Anthocyrtium ehrenbergii pliocenica* rather common, *Calocyclas virginis* rare, and *Eucyrtidium delmontense* absent or very rare. Thus the lighter-coloured portion was probably displaced, either on the sea floor or during sampling, from a level above 6 metres in the core.

late Tertiary. Reworking is indicated by the presence of a very few early Tertiary forms near the top of the core, and middle Tertiary species in the upper and lower sections.

CORE NO. 77 B

Radiolaria are well-preserved and abundant in the two samples from this core. The sediment is probably Quaternary, with admixture of early Tertiary (particularly in the lower part), and some middle and late Tertiary species.

CORE NO. 77

The Radiolaria of the top sample examined from this core correspond moderately well with those from the short Core 77 B — the tests are well-preserved and abundant, and indicate a Quaternary assemblage with considerable admixture of early Tertiary (and probably some middle Tertiary) species. All samples below this, however, have very few Radiolaria, and those which are present (early Tertiary with probably some middle Tertiary) are partially

CORE NO. 77 B

Depth below surface of core (cm.)	Early Tertiary					Middle Tertiary					Late Tertiary and Quaternary									
	Eusyringium fistuligerum	*Calocyclas turris*	*Sethamphora mongolfieri*	*Phormocyrtis embolum*	*Dictyophimus babylonis*	*Calocyclas virginis*	*Tympanidium binoctonum*	*Dipodospyris forcipata*	*Dorcadospyris dentata*	*Stichocorys wolfii*	*Eucyrtidium delmontense*	*Panarium penultimum*	*Anthocyrtium ehrenbergii ehrenbergii*	*?Anthocyrtium ehrenbergii pliocenica*	*Lychnodictyum audax*	*Eucyrtidium elongatum peregrinum*	*Acrobotrys tritubus*	*Pterocanium prismatium*	*Pterocanium praetextum*	*Anthocyrtidium cineraria*
6.25—6.5	—	r	r	—	r	—	—	—	—	—	—	—	r	—	—	—	—	—	c	c
25—26	r	—	r	r	r	—	r	—	—	—	—	—	—	—	—	—	—	—	r	c

CORE NO. 77

Depth below surface of core (cm.)	Early Tertiary					Middle Tertiary					Late Tertiary and Quaternary									
	Eusyringium fistuligerum	*Calocyclas turris*	*Sethamphora mongolfieri*	*Phormocyrtis embolum*	*Dictyophimus babylonis*	*Calocyclas virginis*	*Tympanidium binoctonum*	*Dipodospyris forcipata*	*Dorcadospyris dentata*	*Stichocorys wolffii*	*Eucyrtidium delmontense*	*Panarium penultimum*	*Anthocyrtium ehrenbergii ehrenbergii*	*? Anthocyrtium ehrenbergii pliocenica*	*Lychnodictyum audax*	*Eucyrtidium elongatum peregrinum*	*Acrobotrys tribulus*	*Pterocanium prismatium*	*Pterocanium praetextum*	*Anthocyrtidium cineraria*
9—10	r	r	c	r	—	—	r	—	—	—	—	—	—	—	—	—	—	—	r	c
109—110	+	—	+	+	—	—	?	—	—	—	—	—	—	—	—	—	—	—	—	—
209—210	—	—	+	—	?	—	+	?	—	—	—	—	—	—	—	—	—	—	—	—
309—310	—	?	?	?	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
469—470	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
809—810	—	—	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1109—1110	—	—	+	+	+	—	?	—	—	—	—	—	—	—	—	—	—	—	—	—
1309—1310	—	—	?	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

dissolved. The age of the sediment at and below 109 cm. is therefore doubtful — it may be middle Tertiary with considerable admixture of early Tertiary, or it may be a younger sediment from which late Tertiary and/or Quaternary species (generally more delicate) have been removed by dissolution.

CORE NO. 83

Radiolaria are abundant in all four samples examined from this core. The topmost sample contains well-preserved tests, with a predominance of forms apparently Quaternary in age. In the samples from 99—100 cm. and 199—200 cm., the tests show indications of extensive solution — they are predominantly middle Tertiary, with a considerable admixture of early Tertiary species. The Radiolaria at 289—290 cm. are better preserved than those of the two previous samples, and are apparently middle Tertiary with a large proportion of reworked early Tertiary species. There seems little doubt that in this core a thin layer of Quaternary sediment rests disconformably on middle Tertiary.

CORE NO. 85 B

Radiolaria were well-preserved and moderately abundant in all samples examined from this core, but the samples from 18.5—19.5 cm. and 38.5—39.5 cm. were too small to draw conclusions regarding the relative abundance of the various species. In the samples from 1—1.5 cm. and 9.25—9.5 cm., the assemblage is apparently Quaternary, into which many early, middle and late Tertiary species have been reworked. At 28.5—29.5 cm. the reworked Tertiary forms of various ages obscure the

CORE NO. 83

Depth below surface of core (cm.)	Early Tertiary					Middle Tertiary					Late Tertiary and Quaternary									
	Eusyringium fistuligerum	*Calocyclas turris*	*Sethamphora mongolfieri*	*Phormocyrtis embolum*	*Dictyophimus babylonis*	*Calocyclas virginis*	*Tympanidium binoctonum*	*Dipodospyris forcipata*	*Dorcadospyris dentata*	*Stichocorys wolffii*	*Eucyrtidium delmontense*	*Panarium penultimum*	*Anthocyrtium ehrenbergii ehrenbergii*	*? Anthocyrtium ehrenbergii pliocenica*	*Lychnodictyum audax*	*Eucyrtidium elongatum peregrinum*	*Acrobotrys tribulus*	*Pterocanium prismatium*	*Pterocanium praetextum*	*Anthocyrtidium cineraria*
1—2	r	—	r	r	r	—	—	—	—	—	—	—	—	—	—	—	—	—	c	c
99—100	r	—	r	r	r	—	c	c	—	—	—	—	—	—	—	—	—	—	—	—
199—200	r	—	r	r	r	—	c	c	—	—	—	—	—	—	—	—	—	—	—	—
289—290	r	r	c	c	r	—	c	c	—	—	—	—	—	—	—	—	—	—	—	—

CORE NO. 85 B

Depth below surface of core (cm.)	Early Tertiary					Middle Tertiary					Late Tertiary and Quaternary									
	Eusyringium fistuligerum	*Calocyclas turris*	*Sethamphora mongolfieri*	*Phormocyrtis embolum*	*Dictyophimus babylonis*	*Calocyclas virginis*	*Tympanidium hanoctonum*	*Dipodospyris forcipata*	*Dorcadospyris dentata*	*Stichocorys wolfii*	*Eucyrtidium detmontense*	*Panarium penultimum*	*Anthocyrtium ehrenbergii ehrenbergii*	*?Anthocyrtium ehrenbergii pliocenica*	*Lychnodictyum audax*	*Eucyrtidium elongatum peregrinum*	*Acrobotrys tritubus*	*Pterocanium prismaticum*	*Pterocanium praetextum*	*Anthocyrtidium cinctuvia*
1—1.5	r	r	r	—	—	r	—	—	—	r	r	r	—	—	r	r	—	—	c	c
9.25—9.5	r	—	r	r	r	r	r	r	—	r	r	r	—	—	r	r	—	—	c	c
18.5—19.5	+	—	+	—	—	—	—	+	+	+	—	—	—	—	—	—	—	—	—	—
28.5—29.5	r	r	c	r	r	r	r	r	—	r	r	—	—	r	—	—	—	—	—	—
38.5—39.5	+	+	+	—	+	—	—	—	—	+	—	—	—	—	—	—	—	—	—	—
48.5—49.5	r	—	c	r	—	r	r	—	—	r	r	—	r	—	—	r	—	—	c	r
78.5—79.5	r	—	r	—	r	r	r	r	—	r	r	—	—	—	—	—	—	—	r	—

Quaternary component, while in the bottom two samples only a few apparently Quaternary forms are found together with early, middle and late Tertiary species.

CORE NO. 85

The upper three samples examined from this core contain many Radiolaria, which are, however, fragmentary and badly dissolved; the species represented are middle Tertiary, with a considerable admixture of early Tertiary. At a depth of 3 metres, and continuing to the bottom of the core, Radiolaria are well-preserved and abundant, apparently ranging in age from latest Tertiary at 3 m. to well down into the Miocene at 10.5 m. At depths in the core from 3 m. to 8 or 9 m., early and middle Tertiary species are mixed with the younger forms.

There are two possible explanations for this superposition of a middle Tertiary assemblage on a late Tertiary sediment. It may be supposed that the early and middle Tertiary forms, which had been contributed to the sediment for a considerable length of time before the deposition of the uppermost 3 m., were suddenly introduced in such amount as to obscure the

CORE NO. 85

Depth below surface of core (cm.)	Early Tertiary					Middle Tertiary					Late Tertiary and Quaternary									
	Eusyringium fistuligerum	*Calocyclas turris*	*Sethamphora mongolfieri*	*Phormocyrtis embolum*	*Dictyophimus babylonis*	*Calocyclas virginis*	*Tympanidium hanoctonum*	*Dipodospyris forcipata*	*Dorcadospyris dentata*	*Stichocorys wolfii*	*Eucyrtidium detmontense*	*Panarium penultimum*	*Anthocyrtium ehrenbergii ehrenbergii*	*?Anthocyrtium ehrenbergii pliocenica*	*Lychnodictyum audax*	*Eucyrtidium elongatum peregrinum*	*Acrobotrys tritubus*	*Pterocanium prismaticum*	*Pterocanium praetextum*	*Anthocyrtidium cinctuvia*
29—30	r	—	c	r	r	r	c	?	?	?	—	—	—	—	—	—	—	—	—	—
129—130	c	r	c	r	r	—	c	?	—	?	—	—	—	—	—	—	—	—	—	—
229—230	r	r	c	r	r	—	r	?	—	?	—	—	—	—	—	—	—	—	—	—
299—300	r	r	r	r	—	r	r	—	—	?	—	—	—	r	—	a	—	c	—	r
399—400	—	—	r	r	—	r	r	—	—	r	—	r	—	—	r	a	—	r	—	r
429—430	r	—	r	r	—	r	r	r	—	r	—	r	—	r	r	a	—	c	—	c
499—500	r	r	—	r	—	r	r	—	—	r	—	r	—	r	—	a	—	c	—	c
599—600	—	r	—	r	—	r	r	—	—	r	r	r	—	—	—	a	—	r	—	r
629—630	—	—	r	—	—	r	r	—	—	—	—	r	—	r	r	a	r	—	—	r
699—700	—	—	r	—	r	r	r	—	—	r	r	r	—	r	r	a[1])	r	—	—	r
799—800	—	—	—	—	—	r	r	—	r	—	r	c	—	r	r	a	r	—	—	r
929—930	—	—	r	—	—	r	—	—	—	—	a	r	—	c	r	r	—	—	—	r
1049—1050	—	—	—	—	—	—	?	—	—	—	a	—	r	c	r	—	—	—	—	—

[1]) In this sample and the two following, the third segment of this species is larger than typical, and inflated.

CORE NO. 87

Depth below surface of core (cm.)	Early Tertiary					Middle Tertiary					Late Tertiary and Quaternary									
	Eusyringium fistuligerum	*Calocyclas turris*	*Sethamphora mongolfieri*	*Pharmocyrtis embolum*	*Dictyophimus babylonis*	*Calocyclas virginis*	*Tympanidium binoctonum*	*Dipodospyris furcipata*	*Dorcadospyris dentata*	*Stichocorys wolffii*	*Eucyrtidium delmontense*	*Panarium penultimum*	*Anthocyrtium ehrenbergii ehrenbergii*	*Anthocyrtium ehrenbergii pliocenica*	*Lychnodictyum audax*	*Eucyrtidium elongatum peregrinum*	*Acrobadrys tribulus*	*Pterocanium prismatium*	*Pterocanium praetextum*	*Anthocyrtidium cineraria*
0—9	—	—	—	—	—	r	r	r	r	r	c	r	—	r	r	r	—	—	c	c
19—20	—	—	—	—	—	r	—	—	—	r	c	—	r	r	—	r	—	—	r	c
29—30	—	—	—	—	—	r	r	—	—	r	c	—	—	—	r	r	—	—	r	r
39—40	—	—	—	—	—	r	r	?	—	—	c	r	r	r	—	c[1])	—	—	—	r
49—50	—	—	—	—	—	r	r	—	—	—	c	c	r	c	r	c	—	—	—	r
59—60	—	—	—	—	—	r	—	—	—	r	c	r	—	c	r	r	—	—	—	c
67—68	—	—	—	—	—	r	—	—	—	r	c	c	r	r	r	c	r	—	—	r
79—80	—	—	—	—	—	r	r	—	—	r	c	c	r	c	r	c	—	—	—	r
99—100	—	—	—	—	—	—	r	—	—	—	c	c	r	c	—	c	—	—	—	r
199—200	—	—	—	—	—	—	—	—	—	—	r	c	—	r	r	c	r	—	—	c
299—300	—	—	—	—	—	r	—	—	—	—	c	c	r	r	r	c	—	—	—	c
399—400	—	—	—	—	—	r	r	—	—	—	c	r	—	c	r	c	—	—	—	r
499—500	—	—	—	—	—	r	r	—	—	—	c	r	—	c	r	r	—	—	—	r
599—600	—	—	—	—	—	r	r	—	—	r	a	—	—	c	r	r	—	—	—	—
699—700	—	—	—	—	—	—	—	—	—	—	a	—	r	c	r	r	—	—	—	—
799—800	—	—	—	—	—	—	—	—	—	—	a	—	—	c	r	c	—	—	—	r
899—900	—	—	—	—	—	r	—	—	—	—	a	—	r	r	r	r	—	—	—	—

[1]) In this sample and those below it, specimens of this species usually have a large, somewhat inflated third segment, similar to those at and below 949 cm. in core no. 73, and 699 cm. in core no. 85.

younger species — a type of slump of middle Tertiary sediment, deposited on a late Tertiary surface to which little, if any, Quaternary sediment has been added. This first explanation would appear to be in accordance with the finding of apparently Quaternary assemblages in the short core 85 B. The alternative explanation is that all of the sediment of Core 85 (at least that below 29 cm.) is late Tertiary in age, that its surface has been at a point of non-deposition for a long time, and that the more delicate late Tertiary and perhaps Quaternary tests have been removed from the uppermost 2—3 m. by dissolution. It is, however, difficult to reconcile this second explanation with the occurrence of well-preserved, apparently Quaternary tests in the nearby core 85 B.

CORE NO. 87

Radiolaria are abundant and well-preserved in all samples examined from this core, but age determinations are difficult because of the apparent reworking of middle and late Tertiary species, particularly towards the top of the core. Probably, the top 20 or 30 cm. is Quaternary, and the sediment from 39 cm. to the bottom of the core late Tertiary. The absence, in all samples, of *Pterocanium prismatium*, and the scarcity of typical *Eucyrtidium elongatum peregrinum*, probably indicates a hiatus in sedimentation, with the thin layer of Quaternary resting on perhaps lower Pliocene or upper Miocene. The author, in his earlier interpretation of this core (RIEDEL, 1952), probably placed the upper limit of the Tertiary at too great a depth below the sediment surface: it is difficult to determine whether or not the common specimens of *Eucyrtidium delmontense* in the middle section of the core have reached their present position through reworking.

CORE NO. 88

Samples were examined from approximately every 10 cm. in this core, from 6 cm. below the

CORE NO. 89

Depth below surface of core (cm.)	Early Tertiary					Middle Tertiary					Late Tertiary and Quaternary									
	Eusyringium fistuligerum	*Calocyclas turris*	*Sethamphora mongolfieri*	*Phormocyrtis embolum*	*Dictyophimus babylonis*	*Calocyclas virginis*	*Tympanidium binoctonum*	*Dipodospyris forcipata*	*Dorcadospyris dentata*	*Stichocorys wolfii*	*Eucyrtidium delmontense*	*Panarium penultimum*	*Anthocyrtium ehrenbergii ehrenbergii*	*?Anthocyrtium ehrenbergii pliocenica*	*Lychnodictyum audax*	*Eucyrtidium elongatum peregrinum*	*Acrobotrys tribulus*	*Pterocanium prismatium*	*Pterocanium praetextum*	*Antocyrtidium cineraria*
0—6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	c	c
89—90	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	c	c
189—190	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	c	c
299—300	—	—	—	—	—	r	c	—	?	r	—	—	—	—	—	r	—	—	r	r
399—400	—	—	+	+	—	—	+	—	?	+	—	—	—	—	—	—	—	—	—	—
499—500	+	—	+	+	—	+	+	—	—	?	—	—	—	—	—	—	—	—	—	—
599—600	—	?	+	—	—	—	+	—	—	?	—	—	—	—	—	—	—	—	—	—
699—700	—	—	—	—	—	—	+	—	—	—	—	—	—	—	—	—	—	—	—	—
799—800	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
899—900	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

surface to the bottom at 173 cm. The top sample (6—7 cm.) is highly zeolitic, containing no radiolarian remains. Samples from 12.5—13.5 cm. and 18.5—19.5 cm. contain abundant Radiolaria, which are however fragmentary, and badly corroded by solution: the only forms recognized here are *Dipodospyris forcipata* and *Tympanidium binoctonum*, both common, indicating a middle Tertiary age. At 29—30 cm. there are a few, extremely corroded unidentifiable radiolarian fragments. Thereafter, to the bottom of the core, the sediment is highly zeolitic and contains no radiolarian remains.

It is possible that the radiolarian zone near the top of the core may be younger than middle Tertiary, the more delicate younger tests having been selectively dissolved. This is considered

CORE NO. 91

Depth below surface of core (cm.)	Early Tertiary					Middle Tertiary					Late Tertiary and Quaternary									
	Eusyringium fistuligerum	*Calocyclas turris*	*Sethamphora mongolfieri*	*Phormocyrtis embolum*	*Dictyophimus babylonis*	*Calocyclas virginis*	*Tympanidium binoctonum*	*Dipodospyris forcipata*	*Dorcadospyris dentata*	*Stichocorys wolfii*	*Eucyrtidium delmontense*	*Panarium penultimum*	*Anthocyrtium ehrenbergii ehrenbergii*	*?Anthocyrtium ehrenbergii pliocenica*	*Lychnodictyum audax*	*Eucyrtidium elongatum peregrinum*	*Acrobotrys tribulus*	*Pterocanium prismatium*	*Pterocanium praetextum*	*Anthocyrtidium cineraria*
26—27	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	c	c
109—110	—	—	r	—	—	—	r	—	—	—	—	—	—	—	—	—	—	—	c	r
209—210	—	—	r	—	r	r	c	—	—	?	—	—	—	—	—	—	—	—	c	r
309—310	—	—	—	—	—	a	a	—	c	c	—	—	—	—	—	—	—	—	—	—
409—410	r	—	—	—	—	a	a	r	c	c	—	—	—	—	—	—	—	—	—	—
509—510	—	—	—	—	—	a	a	r	c	a	—	—	—	—	—	—	—	—	—	—
609—610	—	—	—	—	—	a	a	r	c	a	—	—	—	—	—	—	—	—	—	—
709—710	r	—	—	—	—	a	a	r	c	a	—	—	—	—	—	—	—	—	—	—
809—810	—	—	—	—	—	a	a	r	c	a	—	—	—	—	—	—	—	—	—	—
909—910	—	—	r	r	—	a	a	r	c	a	—	—	—	—	—	—	—	—	—	—
1009—1010	—	—	—	—	—	a	a	r	c	a	—	—	—	—	—	—	—	—	—	—
1109—1110	—	—	r	—	—	a	a	r	c	a	—	—	—	—	—	—	—	—	—	—
1209—1210	—	—	r	—	—	a	a	r	c	a	—	—	—	—	—	—	—	—	—	—
1309—1310	r	—	—	—	—	a	c	c	—	a	—	—	—	—	—	—	—	—	—	—
1409—1410	—	—	—	—	r	a	c	c	—	a	—	—	—	—	—	—	—	—	—	—

CORE NO. 93

Depth below surface of core (cm.)	Early Tertiary					Middle Tertiary					Late Tertiary and Quaternary									
	Eusyringium fistuligerum	*Calocyclas turris*	*Sethamphora mongolfieri*	*Phormocyrtis embolum*	*Dictyophimus babylonis*	*Calocyclas virginis*	*Tympanidium binodonum*	*Dipodospyris forcipata*	*Dorcadospyris dentata*	*Stichocorys wolffi*	*Eucyrtidium delmontense*	*Pavarium penultimum*	*Anthocyrtium ehrenbergii ehrenbergii*	*?Anthocyrtium ehrenbergii pliocenia*	*Lychnodictyum audax*	*Eucyrtidium elongatum peregrinum*	*Acrobotrys tritubus*	*Pterocanium prismatium*	*Pterocanium praetextum*	*Anthocyrtidium cinereum*
0.5—1.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	c	c
99—100	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	c	c
199—200	—	—	—	—	—	—	r	—	—	—	—	—	—	—	—	—	—	—	c	c
299—300	—	—	—	—	—	—	r	—	—	?	—	—	—	—	—	—	—	—	c	r
399—400	—	—	—	—	—	—	—	—	—	—	?	—	—	—	—	—	—	—	c	r
499—500	—	—	—	—	—	—	?	—	—	—	—	—	—	—	—	—	—	—	c	r
599—600	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	c	r
699—700	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	c	c
809—810	—	—	—	—	—	—	—	—	—	—	r	—	—	—	—	—	—	—	c	c
909—910	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	c	c
1009—1010	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	c	r
1107.5—1108.5	—	—	—	—	—	—	r	—	—	—	—	—	—	—	—	—	—	—	c	c
1209—1210	—	—	r	—	—	—	r	—	—	—	—	—	—	—	—	—	—	—	c	r
1309—1310	—	—	—	—	—	—	—	—	—	—	r	—	—	—	—	—	—	—	c	c
1409—1410	—	—	—	—	—	—	—	—	—	—	—	—	—	r	—	—	—	—	c	c
1508—1509	—	—	—	—	r	—	r	—	—	r	r	—	—	—	—	r	—	—	r	c

unlikely, however, because the great development of authigenic zeolites probably indicates a long period of diagenesis.

CORE NO. 89

Radiolaria are abundant and well-preserved in the uppermost three samples examined from this core, but in the lower samples they become progressively fewer and more fragmentary, apparently because of solution. The top 2—3 m. of the sediment is probably Quaternary, the sample at 3 m. shows a mixture of Quaternary (or late Tertiary) and middle Tertiary forms, and below that level only early and middle Tertiary forms were found. It is quite possible that the entire core is Quaternary and/or late Tertiary in age, solution of the more delicate tests accounting for the absence of the younger species in the lower levels.

CORE NO. 91

Radiolaria are well-preserved and abundant in all samples examined from this core. There is little doubt that the upper 2—3 m. of sediment, apparently Quaternary in age, lies disconformably on middle Tertiary which constitutes the remainder of the core. In almost all samples, rare specimens of early Tertiary species indicate a small amount of reworking, and near the disconformity middle Tertiary forms are reworked into the later sediment. With regard to the occurrence of *Dipodospyris forcipata* and *Dorcadospyris dentata*, there is a most interesting change between 12 and 13 metres, which may indicate that the latter species is developed directly from the former, and if this change is widespread it may be useful for the more precise determination of the ages of middle Tertiary radiolarian assemblages.

CORE NO. 93

Radiolaria are abundant and well-preserved in all samples examined from this core. It appears likely that the entire sequence is Quaternary in age, because *Pterocanium prismatium* was not found in any sample, and the rare *Eucyrtidium elongatum peregrinum* in the lowest sample is probably reworked. Rare reworked early, middle and late Tertiary species occur sporadically.

Comments on the Stratigraphy

The general stratigraphy of the cores is summarized in Figure 3. From this figure and the above discussions of the individual cores, it will be seen that long, uninterrupted sequences of Quaternary sediment are probably restricted to three cores, two of them (nos. 74 and 75) from an area apparently corresponding to the zone of relatively rapid deposition which ARRHENIUS has termed the equatorial carbonate facies of the eupelagic area, and the third (no. 93) from an area of calcareous sediment to the west of the Gilbert Islands.

In four cores (nos. 76, 83, 87 and 91), there seems little doubt that a rather thin layer of probably Quaternary sediment rests disconformably on middle or late Tertiary. This, and the common occurrence of reworked earlier species in many sediments, strongly indicate that a considerable amount of sediment has been moved about on the floor of the western Pacific during at least late Tertiary and Quaternary time. The mechanism of this movement is no better known than in 1952, when the author speculated that a more or less continuous agency (? current) was transporting Radiolaria on or near the sea floor. The occurrence of relatively constant amounts of reworked earlier forms through long sediment columns as in cores nos. 73, 85 (below 3 m.) and 91 (below 1 m.) seems to confirm the conclusion that the transporting agency has acted either continuously, or at such short intervals as to obscure intermittence. To some extent, evidence of such intermittence may have been obliterated by the mixing action of burrowing organisms on the sea floor.

There is no radiolarian evidence that any of the cores penetrated into sediments older than middle Tertiary. It is possible to obtain an order of magnitude of the general rate of sedimentation in the area represented by the cores. If the upper limit of common *Pterocanium prismatium* and/or *Eucyrtidium elongatum peregrinum* is taken to represent approximately the top of the Tertiary, the amount of Quaternary represented in many of the cores is small (one or a few metres), largely because of interruptions to sedimentation. If the upper limit of common *Eucyrtidium delmontense* can be taken to represent approximately the top of the Miocene, post-Miocene deposition has accounted, in the five cores at which this level can be determined, for 12.5—13.5 m., 5—6 m., less than 1 m., 8—9 m., and 2—3 m. of sediment respectively.

Taxonomy

In this section, the species used as age-indicators are defined and discussed. Previous species descriptions have been modified where necessary, but no attempt has been made to amend genera although the desirability of doing so is evident in some of the discussions. A more thorough taxonomic revision of Pacific Radiolaria will be the objective of later research, as it appears desirable to amend HAECKEL's classification at the generic and even familial levels.

Genus PANARIUM HAECKEL, 1882

Panarium penultimum n. sp.

Plate 1, figure 1

Cortical twin-shell shell constricted equatorially, with circular to irregularly rounded pores: its surface bearing prominent, obtuse protuberances. Distal chambers hemispherical, as caps on either end of cortical twin-shell, their length usually 0.2—0.3 that of twin-shell, somewhat narrower than twin-shell. Each cap surmounted by a spongy tube or tongue-shaped column, of which the width is approximately half that of the maximum breadth of twin-shell, or less. Outer medullary shell lenticular, inner one spherical.

Length of cortical twin-shell usually 100—120 μ, its maximum breadth 80—105 μ. Length

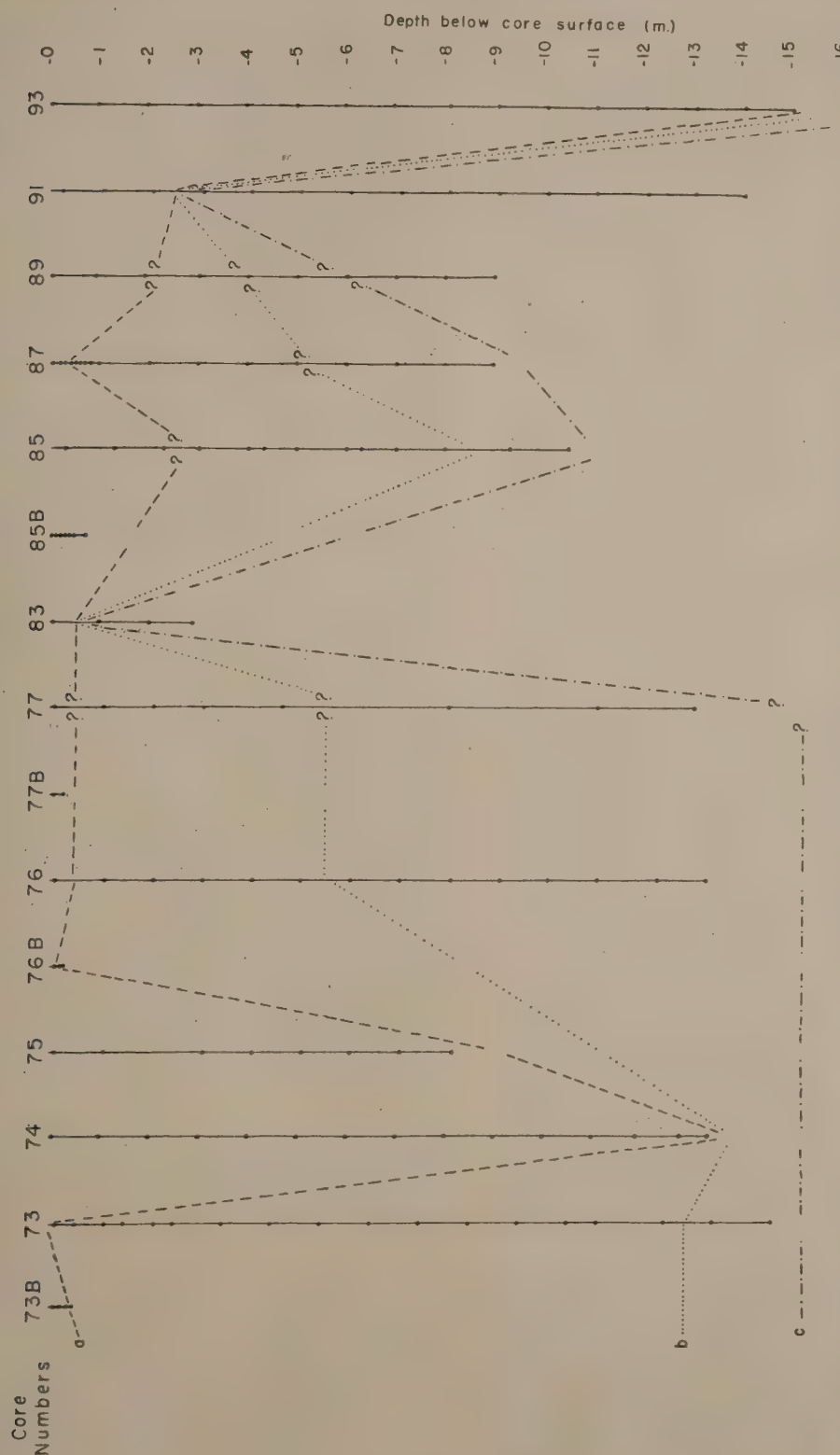

Figure 3. General stratigraphy of the cores. Solid lines indicate cores, with large dots at the positions of the samples. a (dashed line), upper limit of common *Pterocanium prismatium* and/or *Eucyrtidium elongatum peregrinum* (tentatively »top of the Pliocene«). b (dotted line), upper limit of common *Eucyrtidium delmontense* (tentatively »top of the Miocene«). c (dot-dash line), upper limit of middle Tertiary.

of polar caps 25—40 μ, of spongy polar columns 25—80 μ.

This species differs from other described members of the genus in the heavy protuberances of the cortical twin-shell.

Localities. — Swed. D. S. Exped. Core 73 B, 10—39 cm.; Core 73, 212 cm., 749—1471 cm.; Core 76 B, 10— 25.5 cm.; Core 76, 7.5—509.5 cm.; Core 85 B, 1—9.5 cm.; Core 85, 399—930 cm.; Core 87, 0—9 cm., 39—500 cm.

Discussion. — Some of HAECKEL's terms for the description of *Panarium* and related genera are unsatisfactory, and modifications of the terminology are desirable. The cortical shell in the Panartida and Zygartida is, according to HAECKEL's terminology, divided by three or more parallel strictures into four or more chambers. However, the two proximal chambers, corresponding to the entire cortical shell of *Artiscus*, constitute an entity which is quite distinct from the cap-like distal chambers. It is therefore proposed that the two proximal chambers of the cortical shell in the Panartida and Zygartida be termed the »cortical twin-shell» (a term used by HAECKEL in the Artiscida and Cyphinida), and that the distal chambers be termed »polar caps».

The polar terminations of the species here described are spongy columns rather than »hollow fenestrated tubes», but it seems undesirable to erect a seperate genus based on this character. The definition of the genus *Panarium* should therefore be somewhat broadened to include forms in which the polar columns are spongy, and not hollow.

Although *Panarium penultimum* has not been found in any well-dated subaerial sediment, it appears to be a useful age-indicator in the Pacific sediment cores. In cores nos. 73, 76, 85 and 87, it occurs together with *Eucyrtidium elongatum peregrinum* in samples which are considered to be very late Tertiary in age, and it apparently does not extend far downward beyond the upper limit of common *Eucyrtidium delmontense*. In each of these four cores, there are indications that it was developed from a form having less conspicuous polar caps, and wider terminal spongy columns.

Genus TYMPANIDIUM HAECKEL, 1882

Tympanidium binoctonum Haeckel

Plate 1, figure 2

Typanidium binoctonum Haeckel 1887, p. 1004, Pl. 94, fig. 18.

HAECKEL's classification of the Stephoidea is complex, and probably to a large extent artificial, and an attempt to revise it to show true natural relationships would involve a long and intensive study of forms of which topotypic material is at present not available to the author. Although there are indications that HAECKEL's description of *T. binoctonum* is too restricted, and that it may later have to be expanded to include a greater range of variation, it is found that forms corresponding to the original description and figure are widely distributed in middle Tertiary sediments and can conveniently be used as indicators of assemblages of this age. For the purposes of this investigation, therefore, the name is applied only to those forms composed of smooth rods, and having a markedly octagonal outline.

Localities. — »Challenger» Station 225, N 11° 24′ E 143° 16′, depth 4475 fm. (Haeckel). Probably middle Tertiary (RIEDEL, 1954).

Oligocene chalky marl near Jeremie, Haiti (RIEDEL, 1954).

Cipero formation (upper Oligocene) at Golconda Estate, Trinidad (RIEDEL, 1954).

Upper Oligocene or lower Miocene siliceous clay, Andaman Islands (RIEDEL, 1954).

Probably upper Oligocene sediment from »Challenger» Station 268, N 7° 35′ W 149° 49′, depth 2900 fm. (RIEDEL, 1954).

Swed. D. S. Exped. Core 73 B, 10—49 cm.; Core 73, 12—1471 cm.; Core 76 B, 10 cm.; Core 76, 1229 and 1329 cm.; Core 77 B, 25 cm; Core 77, sporadically; Core 83, 99—290 cm.; Core 85 B, sporadically; Core 85, 29—800 cm., and doubtfully at 1050 cm.; Core 87, sporadically; Core 88, 13 and 19 cm.; Core 89, 299—700 cm.; Core 91, 109—1410 cm.; Core 93, sporadically.

Genus DIPODOSPYRIS HAECKEL, 1882

Dipodospyris forcipata Haeckel

Plate 1, figure 3

Dipospyris forcipata Haeckel 1887, p. 1037, Pl. 85, fig. 1.

Shell subspherical to nut-shaped, tuberculate, with circular to subcircular pores separated by thick intervening bars. Horn thick, cylindrical, tapering to a point, approximately as long to 3 times as long as shell. Feet long, thick, cylindrical, almost semicircular or sometimes slightly recurved distally, with their convergent ends often separated, sometimes crossed.

Length of apical horn usually 100—200 μ, of shell 75—85 μ, of feet (straight-line distance from origin to tip) 230—350 μ. Breadth of shell 95—115 μ.

This species differs from *D. irregularis* Haeckel in longer horn and more regular form of feet, and from other described species in longer feet and/or tuberculate shell.

Localities. — »Challenger» Stations 263—268, N 17° 33′ W 153° 36′ to N 7° 35′ W 149° 49′, depths 2650—3000 fm. (HAECKEL), but see discussion below.

Upper Oligocene part of the Cipero formation at Retrench Quarry and Golconda Estate, Trinidad.

Oligocene chalky marl of the sea cliff 1/2 mile S. E. of the plaza, Jeremie, Haiti.

Swed. D. S. Exped. Core 73 B, 10—49 cm.; Core 73, sporadically; Core 77, doubtfully at 209 cm.; Core 83, 99—290 cm.; Core 85 B, sporadically; Core 85, 429 cm., and doubtfully at 29—230 cm.; Core 87, 0—9 cm., and doubtfully at 39 cm.; Core 88, 13 and 19 cm.; Core 91, 409—1410 cm.

Discussion. — With the object of determining the range of variation of this species, small portions of the original sediment samples from »Challenger» Stations 263 and 265—268 were examined. Although HAECKEL states that *D. forcipata* occurs at all these localities, the author found no specimens of the genus *Dipodospyris* at any but Station 268, where they are rather common. Considerably more variation was found within the species than was indicated by HAECKEL, and the description is therefore emended.

As the only well-dated sediments in which the species has been found are Oligocene, *D. forcipata* may tentatively be regarded as restricted to the middle Tertiary.

Genus DORCADOSPYRIS HAECKEL, 1882

Dorcadospyris dentata Haeckel

Plate 1, figure 4

Dorcadospyris dentata Haeckel 1887, p. 1040, Pl. 85, fig. 6.

Dorcadospyris decussata Haeckel 1887, p. 1041, Pl. 85, fig. 7.

Shell subspherical, smooth to tuberculate, with circular or subcircular pores separated by thick intervening bars, bearing a smooth, cylindro-conical apical horn which is as long to four times as long as the shell. Two basal-lateral feet thick, subcylindrical, curved, almost semicircular or sometimes somewhat S-shaped, departing from the shell approximately at right angles, with distal ends approaching, crossing, or fused with one another. Convex side of each foot having a series of usually 4—10 simple

conical spines which vary considerably in their state of development.

Length of apical horn usually 70—230 μ, of shell 60—75 μ, of feet (straight-line distance from proximal to distal end) 250—450 μ, of spines on feet 5—125 μ. Breadth of shell 80—95 μ.

This species differs from *D. antilope* Hackel and *D. lunulata* Haeckel in smaller number of spines on feet, and from *D. dinoceras* Haeckel in simple apical horn. It differs from described species of *Stephanospyris* in absence of verticils of teeth on the apical horn.

Localities. — »Challenger» Stations 265—274, N 12° 42′ W 152° 1′ to S 7° 25′ W 152° 15′, depths 2350—2925 fm. (Haeckel), but see discussion below.

Upper Oligocene (Zone 2) of the Cipero formation at Retrench Quarry and Golconda Estate, Trinidad.

Swed. D. S. Exped. Core 73 B, 10 and 48 cm.; Core 73, sporadically; Core 85 B, 19 cm.; Core 85, sporadically; Core 87, 0—9 cm.; Core 89, doubtfully at 300 and 400 cm.; Core 91, 309—1210 cm.

Discussion. — In order to determine the ranges of variation of *D. dentata* and *D. decussata*, the author examined small parts of the original sediment samples collected at »Challenger» Stations 265—268, 270 and 272. No specimens of the genera *Dorcadospyris* or *Stephanospyris* were found in the samples from stations 265—267, and 270 — indicating that if present, they are very rare. Two specimens corresponding with Haeckel's description of *D. dentata* were found in the sample from station 272. In the sample from station 268 many specimens of *Dorcadospyris* were found, all corresponding to the above emended description of *D. dentata*. It appears to be impossible to distinguish the two species *D. dentata* and *D. decussata* as Haeckel has done, on the basis of the length of the apical horn, and »crossed», or »not crossed» feet.

Occasionally, specimens of *D. dentata* have the distal ends of the feet fused in a manner similar to those of *Stephanospyris cordata* Haeckel (1887, p. 1042, Pl. 85, fig. 10). Thus this species indicates that the character (feet forming a ring by union) on which Haeckel differentiated *Stephanospyris* from *Dorcadospyris* should not be used as a generic character, and that the two genera should be synonymized.

The Upper Oligocene of Trinidad is the only well-dated sediment in which this species has been found, and therefore it may be tentatively regarded as restricted to the middle Tertiary. Wherever it occures in deep-sea sediments, it is accompanied by other species considered to indicate a probably middle Tertiary age.

Genus ACROBOTRYS Haeckel, 1882

Acrobotrys tritubus n. sp.

Plate 1, figure 5

Cephalis trilobate, with large subglobular occipital lobe, smaller globular middle lobe, and inflated-conical frontal lobe lying in the same plane. Occipital lobe bears two slender cylindrical tubes, one directed apically and the other posteriorly. Frontal lobe bears a slender cylindrical tube directed anteriorly. Thorax subcylindrical, inflated, or ovate, often with somewhat constricted mouth. Shell surface smooth, perforated by numerous small circular or subcircular pores, irregularly arranged.

Length of cephalis plus thorax 90—125 μ, of tubes 15—120 μ. Maximum breadth of thorax 50—60 μ.

This species closely resembles *A. disolenius* Haeckel, from which it differs principally in bearing two tubes on the occipital lobe. It differs from *A. trisolenius* Haeckel in having a trilobate cephalis.

Localities. — Swed. D. S. Exped. Core 73, 949—1112.5 cm.; Core 76 B, 10—20.5 cm.; Core 76, 108.5—509.5 cm., 1110 cm.; Core 85, 629—800 cm.; Core 87, 67 cm. and 200 cm.

Discussion. — Although this species has not been found in any sediments other than those collected from the floor of the Pacific Ocean, the pattern of its occurrence in the cores indicates that it may be a useful marker for part of the upper Tertiary. In cores nos. 73, 76, 85 and 87, it occurs in a rather narrow zone just above the level of the latest occurrence of common or abundant *Eucyrtidium delmontense*.

The termination of the trivial name of the new species is consistent with the masculine gender of the generic name, and the terminations of HAECKEL's *A. disolenia* and *A. trisolenia* are changed accordingly.

Genus DICTYOPHIMUS EHRENBERG, 1847

Dictyophimus babylonis Clark and Campbell

Plate 1, figure 6

Dictyophimus babylonis Clark and Campbell 1942, p. 67, Pl. 9, figs. 32 and 36.

This species, observed by the present author in a number of Eocene localities, always agrees well with the original description and figure except that some specimens have a pronounced collar-like peristome around the mouth, and the horn and feet are sometimes less stout.

Length of horn usually 30—50 μ, of cephalis 20—25 μ, of thorax 80—100 μ, of feet 50—80 μ. Maximum breadth of thorax 85—100 μ.

Dictyophimus babylonis shows marked similarity to *D. lucerna* (Ehrenberg), and its common occurrence in the upper Eocene part of the Oceanic formation of Barbados suggests that the two may be identical. However, the much greater angularity of the thorax in EHRENBERG's figure (EHRENBERG 1856, Pl. 36, fig. 6; 1876, Pl. 8, fig. 3) indicates that he may have found a different but closely related species.

Localities. — Upper Eocene Kellog and Sidney shales, near Mt Diablo, California (CLARK and CAMPBELL).

Eocene part of the Oceanic formation at Bath, Mt. Hillaby, and Hopefield Plantation, Barbados.

Lower Eocene Toledo member of the Universidad formation, Cantera Central Toledo, Habana Province, Cuba.

Upper Eocene outcrop cored by Stetson (1949) on the continental slope off New Jersey, U. S. A.

Middle Eocene at Beit Jibrin, Israel.

Swed. D. S. Exped. Core 73 B, 10—49 cm.; Core 73, 50 cm.; Core 76 B, 10 cm.; Core 76, 209 cm.; Core 77 B, 6.5 and 25 cm.; Core 77, 209—1110 cm. (sporadically); Core 83, 1—290 cm.; Core 85 B, 9.5—79.5 cm. (sporadically); Core 85, 29—230 cm. and 700 cm.; Core 91, 210 and 1410 cm.; Core 93, 1508 cm.

Genus LYCHNODICTYUM HAECKEL, 1882

Lychnodictyum audax Riedel

Lychnodictyum audax Riedel 1953, pp. 810—811, Pl. 85, fig. 9.

This species, previously known only from a probably very late Tertiary sediment on the island of Rotti, near Timor, may prove to be a useful age-indicator in tropical Pacific sediments. In cores which penetrate a long sequence of probably Tertiary sediment, *L. audax* appears to be restricted to the upper part of the Miocene and the Pliocene.

Localities. — Swed. D. S. Exped. Core 73 B, 10—24 cm.; Core 73, 211.5—450 cm. (sporadically), 949—1471 cm.; Core 76 B, 10—25.5 cm.; Core 76, 108.5—1330 cm.; Core 85 B, 1—9.5 cm.; Core 85, 399—430 cm., 629—1050 cm.; Core 87, 0—80 cm. (sporadically), 199—900 cm.

Genus SETHAMPHORA HAECKEL, 1887

Sethamphora mongolfieri (Ehrenberg)

Plate 1, figure 7

Eucyrtidium mongolfieri Ehrenberg 1856, Pl. 36, fig. 18.

Eucyrtidium mongolfieri Ehrenberg 1874, p. 230.

Eucyrtidium mongolfieri Ehrenberg 1876, Pl. 10, fig. 3.

Sethamphora mongolfieri (Ehrenberg). Haeckel 1887, p. 1251.

Sethamphora costata Haeckel 1887, p. 1251, Pl. 62, fig. 3.

Cephalis and thorax rather thick-walled, merged together so as to obliterate collar stricture, with numerous circular to subcircular pores passing obliquely through shell wall, directed (inward) toward cephalis. Lumbar stricture distinct. Abdomen truncate-ovate, with usually 120—230 circular pores in 5—10 transverse rows, and also in longitudinal rows separated by 18—24 pronounced surface ridges: pores thus strictly rectangularly arranged. Mouth generally 0.3—0.5 as wide as maximum shell breadth, surrounded by a short hyaline sub-cylindrical peristome.

Length of cephalis and thorax usually 45—50 μ, of abdomen (including peristome) 75—105 μ. Maximum breadth 70—105 μ.

This species differs from most others of the genera *Sethamphora, Dictyocephalus* and *Theocampe* in general form, rectangular arrangement of abdominal pores, and 18 or more smooth, pronounced, longitudinal abdominal ridges. It apparently differs from *Theocampe costata* Haeckel (? and *Dictyocephalus callimorphos* Clark and Campbell) in obliterated collar stricture.

L o c a l i t i e s. — Probably upper Eocene part of Oceanic formation at »Mount Hillaby, ungefähr 1100 Fuss über dem Meere», »Jeeves oder Boscobelle aus dem Kirchspiel St. Andrew», »Tank Smith House, Chalky Mount im Scotland District», »Springfield, Scotland District», »Burnt Hill», »Gipfel des Bissex Hill», »Gipfel des Mount Hilaby, 1147 Fuss hoch über dem Meere», and several other unspecified localities on Barbados, B. W. I. (Ehrenberg).

»Challenger» Stations 265 to 274, N 12° 42′ W 152° 1′ to S 7° 25′ W 152° 15′, depths 2350—2925 fm. (Haeckel), but see discussion below.

Upper Eocene part of the Oceanic formation at Bath, Mt. Hillaby and Hopefield Plantation, Barbados.

Eocene outcrop cored by Stetson (1949) on the continental slope off New Jersey, U. S. A.

Eocene Densinyama and Hagman formations, Saipan, Mariana Islands (Riedel, in press).

Swed. D. S. Exped. Core 73 B, 10—49 cm.; Core 73, 12—1350 cm. (sporadically); Core 76 B, 20 cm.; Core 76, 8 cm.; Core 77 B, 6.5 and 25 cm.; Core 77, 9—1310 cm. (sporadically); Core 83, 1—290 cm.; Core 85 B, 1—79.5 cm.; Core 85, 29—230 cm., and sporadically from 299—930 cm.; Core 89, 399—600 cm.; Core 91, 109—1210 cm. (sporadically); Core 93, 1210 cm.

D i s c u s s i o n. — Comparison of specimens from the Eocene part of the Oceanic formation of Barbados and from the original sediment sample from »Challenger» Station 265 shows that the form described by Haeckel as *S. costata* is identical with Ehrenberg's *S. mongolfieri*. Both Ehrenberg and Haeckel overlooked the fact that the apical part of the shell consists of a fused cephalis and thorax: Bütschli (1882, p. 528) correctly recognized that *S. mongolfieri* has three segments.

With the object of checking on the reported occurrence of »*Sethamphora costata*» at »Challenger» Stations 265—274, the author examined small portions of the samples from Stations 265—268, 270, and 272, these being the only ones available to him at present. *S. mongolfieri* was found in the first four of these samples, in each of which it was accompanied by other species considered to indicate reworked early Tertiary, but was absent from the other two.

It appears probable that *Dictyocephalus pulcherrimus* Clark and Campbell (1942, p. 78,

pl. 8, figs. 2, 3, 6, 7) also has three segments, and may have to be synonymized with *S. mongolfieri*. No specimens of this species are, however, at present available to the author for comparison. *Dictyocephalus callimorphos* Clark and Campbell (1945, p. 42, pl. 6, fig. 7) and *Theocampe costata* Haeckel (1887, p. 1426, pl. 66, fig. 24) may both be closely allied to, or identical with, *S. mongolfieri:* until it is possible to examine specimens from the type localities, they are separated on the basis of the described distinct collar stricture. If *Theocampe costata* is found to be identical with *S. mongolfieri*, this will possibly indicate that its reported occurrence in the surface waters of the Sunda Straits is due to erosion of a Tertiary ediment.

S. mongolfieri is found in many widely-separated Eocene localities, and not in younger or older rocks. On the basis of available data, the species is regarded as being restricted to the early Tertiary.

Genus ANTHOCYRTIUM Haeckel, 1887

Anthocyrtium ehrenbergii ehrenbergii (Stöhr)

Plate 2, figures 1—3

Anthocyrtis ehrenbergi Stöhr 1880, p. 100, Pl. 3, figs. 21 a, b.

Anthocyrtium ehrenbergii (Stöhr). Haeckel 1887, p. 1277.

Cephalis complex, elongate, ovate-cylindrical, with scattered subcircular to circular pores, bearing a three-bladed apical horn usually of approximately the same length as the cephalis. Thorax with usually flat surface, campanulate, inflated, with constricted mouth, having circular pores hexagonally arranged, rarely hexagonally framed. Some specimens have no subterminal teeth, but many have approximately 3—8, while very rare individuals have 10—20 well-developed, sharp subterminal teeth up to 10 μ long. Surrounding the constricted mouth is a lamellar peristome which usually bears 10—20 well developed, flat, triangular terminal teeth — these peristomial teeth occasionally poorly developed, rarely absent.

Length of apical horn usually 25—50 μ, of cephalis 35—50 μ, of thorax 89—105 μ, of peristomial teeth 5—10 μ. Breadth of cephalis usually 30—35 μ, of thorax 95—115 μ.

This species is distinguished from most others included in the genus *Anthocyrtium* by the circular pores set in a flat thoracic wall, and the flat triangular teeth at the edge of the definite peristome. *A. zanguebaricum* (Ehrenberg) has apparently less regular thoracic pores, and in *Anthocyrtis ovata* Haeckel the apical horn is described as conical and the mouth as less constricted. *Anthocyrtium ehrenbergii ehrenbergii* differs from *Anthocyrtidium cineraria* Haeckel in the usually flat thoracic surface, and in that the peristomial teeth are generally much more strongly developed than the subterminal teeth.

Localities. — Miocene »Tripoli» of Grotte, Sicily (Stöhr).

Middle or upper Miocene of Salsomaggiore, Italy, according to Lucchese (1927, p. 104) — though the dimensions which he records are much larger than those found elsewhere.

Swed. D. S. Exped. Core 73 B, 23 cm.; Core 73, 1112 cm.; Core 76 B, 20—25.5 cm.; Core 76, 309 cm. and 708.5—1330 cm.; Core 77 B, 6.5 cm.; Core 85 B, 49 cm.; Core 85, 1050 cm.; Core 87, 19—900 cm. (sporadically).

Discussion. — Despite the generic separation of this species from *Anthocyrtidium cineraria* in Haeckel's system, there is little doubt that the two are very closely related. It seems possible, in fact, that the more recent *Anthocyrtidium cineraria* may have arisen from a late Tertiary ancestor identical with, or very similar to, *Anthocyrtium ehrenbergii* (see discussion of this species). The cephalis of *A. ehrenbergii* is lobed in a manner similar to that of *Anthocyrtidium cineraria* and

Calocyclas virginis (Figs. 4 and 5), and this character alone is probably sufficient to indicate lack of relationship of the species to the majority of the others which Haeckel placed in the genus *Anthocyrtium*.

It is difficult, with the data available, to distinguish *Anthocyrtium ehrenbergii* satisfactorily from *A. zanguebaricum* (Ehrenberg) and *Anthocyrtis ovata* Haeckel. The description and figure of *Anthocyrtium zanguebaricum* indicate that the thorax is narrower than that of *A. ehrenbergii*, and that the thoracic pores are less regular: restudy of material from the original locality is necessary, however, to establish differences and similarities. The author has examined original sediment material (including an estimated 50 000 well-preserved Radiolaria) from »Challenger» Station 272, the type locality of *Anthocyrtis ovata*, but has found no specimen agreeing with Haeckel's description of this species: it is therefore impossible satisfactorily to distinguish this species from *Anthocyrtium ehrenbergii*.

There is little data on which to base the stratigraphic range of this species, but its occurrence in the Sicilian Miocene, and its absence both in deep-sea sediments considered to be Quaternary and in sediments known to be older than Miocene indicates that it may be restricted to the upper Tertiary.

Anthocyrtium ehrenbergii (Stöhr) var. **pliocenica** (Seguenza)

Plate 2, figures 4 and 5

Anthocyrtis ehrenbergii Stöhr var. *pliocenica* Seguenza 1880, p. 232.

Similar to *A. ehrenbergii ehrenbergii*, except in the presence of approximately equally developed subterminal and peristomial teeth, and somewhat larger thoracic pores in relation to the intervening bars.

Length of apical horn usually 32—60 μ, of cephalis 35—40 μ, of thorax 90—115 μ, of feet 5—20 μ. Breadth of cephalis 25—32 μ, of thorax 90—120 μ.

Localities. — Pliocene of Ardore, Calabria, Italy (Seguenza).

Swed. D. S. Exped. Core 73, 1049—1471 cm.; Core 76 B, 10—25.5 cm.; Core 76, 108.5—1110 cm., 1330 cm.; Core 85 B, 29 cm.; Core 85, 299—500 cm. (sporadically), 629—1050 cm.; Core 87, 0—20 cm., 39—900 cm.; Core 93, 1410 cm.

Discussion. — Seguenza's description of this variety is brief, and he gives no figure, so that the identification of the form found in the Pacific sediments must remain doubtful until it can be compared with material from the type locality.

In the characters of the teeth and of the thoracic wall, this form appears to be intermediate between *Anthocyrtium ehrenbergii ehrenbergii* and *Anthocyrtidium cineraria*. One is therefore tempted to speculate that it may represent an intermediate phylogenetic stage between these two species. There is, however, too little evidence for such a conclusion, and it is possible to say only that *Anthocyrtium ehrenbergii pliocenica* may be restricted to the upper Tertiary, and that it is difficult to distinguish, at the extremes of its range of variation, from the other two species mentioned above.

Genus ANTHOCYRTIDIUM Haeckel, 1882

Anthocyrtidium cineraria Haeckel

Plate 2, figures 6—9; Figure 4

Anthocyrtidium cineraria Haeckel 1887, p. 1278, Pl. 62, fig. 16.

Sethocyrtis oxycephalis Haeckel 1887, p. 1299, Pl. 62, fig. 9.

Cephalis complex, elongate, ovate-cylindrical, with subcircular pores, bearing a three-bladed apical horn usually of about the same length as the cephalis. Thorax campanulate, inflated,

with constricted mouth, having circular to subcircular pores hexagonally arranged, usually hexagonally framed, separated by rather delicate bars. Subterminal row of 8—11 sharp, 3-bladed teeth usually prominent, but in some individuals absent or scarcely discernible. Distally from the subterminal teeth, the thoracic wall curves inward abruptly, to terminate at a narrow delicate lamellar peristome. One or two thoracic pores between subterminal teeth and peristome. Peristome often bears inconspicuous, small triangular teeth directed either downward or inward, forming a terminal row.

Length of apical horn usually 30—50 μ, of cephalis 30—40 μ, of thorax 90—105 μ, of subterminal teeth (when present) 5—30 μ. Breadth of cephalis usually 25—35 μ, of thorax 100—130 μ.

This species differs from *Anthocyrtidium ligularia* Hackel and *A. matricaria* Haeckel in the small sharp subterminal teeth and general form of the thorax. It differs from *Anthocyrtium ehrenbergii* (Stöhr) var. *pliocenica* (Seguenza) in the usually poorly-developed peristomial teeth.

Localities. — »Challenger» Stations 263 (N 17° 33′ W 153° 36′) to 274 (S 7° 25′ W 152° 15′); depth 2350—3000 fm. (Haeckel).

Swed. D. S. Exped. cores from the tropical Indian Ocean (Riedel, 1952).

Swed. D. S. Exped. Core 73 B, 10—39 cm.; Core 73, 11.5—848 cm., 1250 cm.; Core 74, 1—1340 cm.; Core 75, 9—820 cm.; Core 76 B, 10—25.5 cm.; Core 76, 7.5—509.5 cm.; Core 77 B, 6.5 and 25 cm.; Core 77, 10 cm.; Core 83, 1 cm.; Core 85 B, 1—9.5 cm., 49 cm.; Core 85, 299—930 cm.; Core 87, 0—500 cm., 800 cm.; Core 89, 0—300 cm.; Core 91, 26—210 cm.; Core 93, 0.5—1509 cm.

Discussion. — There is little doubt that *Sethocyrtis oxycephalis* should be placed in synonymy with *Anthocyrtidium cineraria*. The state of development of both the subterminal and peristomial rings of teeth varies among individuals of the species, and occasional specimens are found with no teeth developed: it is apparently these latter on which Haeckel based the description of the eradiate form. This is found to be the case not only in the Swed. D. S. Exped. cores, but also in the original »Challenger» samples nos. 265, 266, 270 and 272, from the area from which Haeckel first described *S. oxycephalis*.

Placing *S. oxycephalis* as a synonym of *A. cineraria* raises a rather complicated taxonomic problem. Haeckel did not designate type species of either *Anthocyrtidium* or *Sethocyrtis*. Campbell (1954) designated *S. oxycephalis* as the type species of *Sethocyrtis*, and states that *A. cineraria* is the type species of *Anthocyrtidium* — apparently also by subsequent designation. Thus, technically, *Sethocyrtis* becomes a subjective synonym of *Anthocyrtis*. However, there are other species which Haeckel placed in the genus *Sethocyrtis*, e. g. *S. subacuta* (Ehrenberg) and *S. agamemnonis* Haeckel, and which should probably remain generically separated. A new generic name may therefore be necessary to include those species which when fully developed have characters conforming to the definition of *Sethocyrtis*, unless another species be designated as type of that genus.

It also appears possible that the forms described by Ehrenberg as *Eucyrtidium pleuracanthus* and *Anthocyrtis ophirensis* should be grouped together with this species. To judge from the first record of *E. pleuracanthus* (Ehrenberg 1861 a, p. 768), the species may have been described on the basis of a single specimen: if the peristomial and subterminal teeth were small, they may have been overlooked by Ehrenberg, or it may have been one of the poorly-developed individuals without teeth. Ehrenberg's figure of *A. ophirensis* (Ehrenberg 1873, Pl. 9, fig. 13) shows remarkable similarity

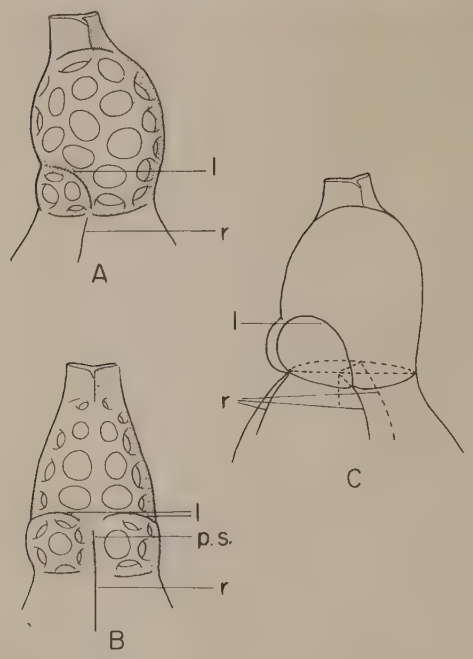

Figure 4. Lobed cephalis of *Anthocyrtidium cineraria*. *A* and *B*, sketches of two views (at right angles to one another), showing indications of the primary sagittal ring (p. s.) and two lateral furrows (l.), and thoracic ribs (r.); *C*, idealized diagram showing relation of cephalic lobes and thoracic ribs to the two pairs of basal pores.

to a well-developed *Anthocyrtidium cineraria*, and it is possible that he may have overlooked a part of the shell inside the subterminal teeth. However, further work on assemblages from the type localities of those forms is necessary before any decision can be reached.

The cephalis of *Anthocyrtidium cineraria* often has, to a greater or less extent, a lobate form similar to that found in *Calocyclas virginis*. In most specimens, it is possible to distinguish two lobes, bounded by part of the primary sagittal ring and two lateral furrows, toward the base of the main part of the cephalis (Figure 4). It is also often possible to distinguish, though neither distinctly nor consistently, three ribs in the thoracic wall: to judge from their relation to the collar pores, these ribs represent the caudal and pectoral feet in the sense of HAECKEL.

In those cores (nos. 76, 85 and 87) which extend down into upper Tertiary sediments, the development of *Anthocyrtidium cineraria* can tentatively be traced from forms having relatively more pronounced peristomial teeth. It appears that *Anthocyrtium ehrenbergii ehrenbergii* (Stöhr), a rather common Miocene form having pronounced peristomial teeth and no subterminal teeth, is closely related to a form — probably that described as *Anthocyrtis ehrenbergii* Stöhr var. *pliocenia* Sequenza — having both well-developed peristomial and subterminal teeth. Later the peristomial teeth seem to have tended to disappear, with the development of *Anthocyrtidium cineraria*. Accompanying this apparent decrease in the development of the peristomial teeth, there ocurred a change in the nature of the general shell surface from the flat surface of the Miocene forms to the often hexagonally framed Recent type which is formed of relatively thin bars. On the basis of available evidence, the time-range of *A. cineraria* may tentatively be regarded as Pliocene-Recent.

Genus PTEROCANIUM EHRENBERG, 1847

Pterocanium praetextum (Ehrenberg)

Plate 3, figures 1—3

Lychnocanium praetextum Ehrenberg 1872, p. 316.

Lychnocanium praetextum Ehrenberg 1873, Taf. 10. fig. 2.

Pterocanium praetextum (Ehrenberg). Haeckel 1887, pp. 1330—1331.

Pterocanium virgineum Haeckel 1887, p. 1330, Pl. 73, fig. 6.

Cephalis subspherical, with closely-spaced pittings probably representing infilled pores. Apical horn usually cylindro-conical, occasionally angular, as long to twice as long as cephalis breadth. Thorax basically hemispherical, but with shape greatly modified by swellings between the 3 thoracic ribs, resulting in resemblance to a 3-cornered biretta in which the thoracic ribs are situated in depressions across the faces. Thoracic pores subcircular to subangular, separated by relatively thin bars. Feet

3-bladed, proximally fenestrated, curved with convexity outward near thorax, becoming almost straight distally, sub-parallel or slightly divergent, tapering to a point. Abdomen thin-walled, varying in state of development, having small subcircular to angular pores over most of its area, with a row of larger pores adjacent to the feet and in some individuals also along edge of thorax.

Length of apical horn 30—50 μ, of cephalis 14—20 μ, of thorax 50—60 μ, of abdomen 5—120 μ, of feet 75—165 μ. Breadth of cephalis 22—30 μ, of thorax 70—90 μ.

This species differs from others of the genus in the biretta-shaped thorax and generally straight, almost parallel feet.

Localities. — Sediment from sea-floor between Zanzibar and the Comoro Is.; depth 13 200 ft. (EHRENBERG).

Indian Ocean near Ceylon (HAECKEL).

»Challenger» Station 271, S 0° 33′ W 151° 34′; depth 2425 fm. (HAECKEL).

Swed. D. S. Exped. Core 73 B, 10—39 cm.; Core 73, 11.5—450 cm. (sporadically); Core 74, 1—1340 cm.; Core 75, 9—820 cm.; Core 76 B, 10—20 cm.; Core 76, 8 cm.; Core 77, 6.5 and 25 cm.; Core 77, 10 cm.; Core 83, 1 cm.; Core 85 B, 1—9.5 cm., 49 and 79 cm.; Core 87, 0—30 cm.; Core 89, 0—300 cm.; Core 91, 26—210 cm.; Core 93, 0.5—1509 cm.

Discussion. — The author has not been able to examine topotypic material of Ehrenberg's *Lychnocanium praetextum* and Haeckel's *Pterocanium virgineum*, but examination of specimens from nearby samples (the upper parts of Swed. D. S. Exped. cores nos. 153, 154, 155 and 74 B, and the sediment samples collected at »Challenger» stations 270 and 272) leaves little doubt that those two names refer to the same species. The differences in size and the characters of the abdomen and feet which distinguish the two descriptions seem to be due to individual variation.

Although the abdomen usually shows 3 concave basal bays, which character according to HAECKEL's classification distinguishes the subgenus *Pterocanarium* (subgenus *Pterocanium* of Campell, 1954), the abdomen of some well-developed individuals has 3 prominent lobes basally, the distinguishing character of the subgenus *Pterocanidium*. Thus the shape of the basal edge of the abdomen cannot be used to distinguish subgenera of this genus. This species is not easily distinguished when it occurs together with forms having divergent feet with greater curvature and/or thorax more nearly hemispherical, e. g. *Pterocanium proserpinae* Ehrenberg, *P. campanella* (Ehrenberg), *P. tricolpum* Haeckel, *P. eucolpum* Haeckel and *P. trilobum* (Haeckel). This may well be due to the fact that these five species represent a generalized type extending further back into the Tertiary, from which the more differentiated *P. praetextum* was developed only in the latest Tertiary. *P. tricolpum*, which the author has previously used as one of the species indicating Quaternary age, is found to be unsatisfactory for this purpose because of the difficulty of distinguishing it satisfactorily from the other species of the more generalized type, and the possibility that it may extend down into at least part of the Miocene.

The time-range of *P. praetextum* may be tentatively stated to be ?Pliocene to Recent. It occurs in the upper parts of most Pacific and Indian Ocean sediment cores, which indicates its wide distribution in the Recent tropical seas, and its earliest known occurrence is in the lower, probably upper Pliocene parts of Swed. D. S. Exped. cores nos. 58 and 62: in the latter two cores it occurs together with *P. prismatium* n. sp.

Pterocanium prismatium n. sp.

Plate 3, figures 4 and 5

Cephalis subspherical, pitted, bearing a sharply pointed, cylindro-conical apical horn with a length of approximately 1.5 times

cephalic diameter, and sometimes smaller accessory spines. Thorax having overall shape of a triangular prism surmounted by an obtuse triangular pyramid, terminating at pronounced collar stricture: this general shape often modified by shallow concavity of the prismatic faces, and slight swellings between the proximal parts of the 3 thoracic ribs. In relation to the general thorax surface, the thoracic ribs are usually depressed in furrows proximally, and raised on ridges distally. Thoracic pores subpolygonal to almost circular, separated by thin bars, arranged approximately hexagonally in apparent longitudinal rows. Upper part of thorax usually bears small spines: these spines often concentrated on the proximal swellings, and thorns often occur on the ridged part of the thoracic ribs. Opening at base of thorax somewhat constricted. Feet three-bladed, proximally fenestrated, straight or slightly curved, usually almost parallel or somewhat divergent, usually shorter than thorax. Abdomen, when present, short, delicate, with irregular meshes smaller than those of thorax, usually entirely separate from and surrounded by the feet.

Usual length of apical spine 28—40 μ, of cephalis 20—26 μ, of thorax 110—132 μ, of feet 60—120 μ, of abdomen 5—50 μ. Breadth of thorax usually 110—150 μ.

This species is readily distinguished from most others of the genus by the generally prismatic form of the thorax. It differs from *Pterocanium virgineum* Haeckel and *P. praetextum* (Ehrenberg) in the relatively shorter feet and larger thorax.

Localities. — Swed. D. S. Exped. Core 73 B, 10—24 cm.; Core 73, 11.5—750 cm., 950 cm.; Core 76 B, 10—20.5 cm.; Core 85, 299—600 cm.

Discussion. — Although this species has been found at only a very few localities, there are strong indications that it may be a useful age-indicator for Pacific sediments. It occurrs in the lower parts of Swed. D. S. Exped. cores nos. 58 and 62, which ARRHENIUS (1952) dates as uppermost Tertiary. In cores 73, 76 B and 85, *Pterocanium prismatium* is associated with *Eucyrtidium elongatum peregrinum* Riedel (1953), which was described from a probably Pliocene sediment. Thus this species of *Pterocanium* may be an indicator of a time-zone near the top of the Tertiary.

Genus PHORMOCYRTIS HAECKEL, 1887

Phormocyrtis embolum (Ehrenberg)

Plate 3, figures 6 and 7

Eucyrtidium embolum Ehrenberg 1874, p. 228.

Eucyrtidium embolum Ehrenberg 1876, Pl. 10, fig. 5.

Phormocyrtis embolum (Ehrenberg). Haeckel 1887, p. 1369.

Phormocyrtis proxima Clark and Campbell 1942, pp. 82—83, Pl. 7, figs. 24, 26.

Cephalis subspherical, usually with rounded depressions representing infilled pores, bearing a short stout bladed apical horn. Collar stricture moderate to pronounced. Thorax almost conical, slightly inflated, with 16—20 pronounced longitudinal ridges separating uniserial rows of circular pores which are hexagonally arranged. Lumbar stricture slight or absent. Abdomen subcylindrical or inverted truncate conical, with longitudinal ridges and pores similar to those of thorax except for less regular arrangement. Abdominal margin irregular, lamellar, or with parallel lamellar teeth in positions continuous with ridges.

Length of apical horn usually 10—35 μ, of cephalis 20—30 μ, of thorax 50—80 μ, of abdomen 30—90 μ. Maximum breadth of thorax 60—95 μ.

This species differs from *P. ligulata* Clark and Campbell in generally smaller size and less inflated thorax, and from *P. costata* Haeckel in fewer longitudinal ribs and smaller size.

Localities. — Oceanic formation of Barbados (EHRENBERG).

»Challenger» Stations 265 to 268, N 12° 42′ W 152° 1′ to N 7° 35′ W 149° 49′, depths 2700—2900 fm. (HAECKEL).

Upper Eocene Sidney shale, Mt. Diablo area, California (CLARK and CAMPBELL).

Upper Eocene part of the Oceanic formation at Bath, Mt. Hillaby and Hopefield Plantation, Barbados.

Eocene outcrop cored by STETSON (1949) on the continental slope off New Jersey, U. S. A.

Lower Eocene Toledo member of the Universidad formation at Cantera San Francisco, Puentes Grandes, Habana Province, Cuba.

Swed. D. S. Exped. Core 73 B, 10—49 cm.; Core 73, 11.5—1471 cm. (sporadically); Core 76 B, 10 and 25 cm.; Core 76, 7.5 cm.; Core 77 B, 25 cm.; Core 77, 9—1110 cm. (sporadically); Core 83, 1—290 cm.; Core 85 B, 9.5—49.5 cm. (sporadically); Core 85, 29—600 cm.; Core 89, 400 and 500 cm.; Core 91, 910 cm.

Discussion. — A comparison of specimens from the Eocene part of the Oceanic formation of Barbados and from the Sidney shale of the Mt. Diablo area in California shows that there are no consistent differences between Ehrenberg's *Phormocyrtis embolum* and Clark and Campbell's *P. proxima*. The species are therefore synonymized under the former name.

P. embolum has been found in several widely separated Eocene localities, and not in any of the purely younger or older sediments examined; on the basis of this data it can be tentatively regarded as restricted to the Eocene.

Genus CALOCYCLAS EHRENBERG, 1847

Calocyclas turris Ehrenberg

Plate 3, figure 8; Plate 4, figures 1 and 2

Calocyclas turris Ehrenberg 1874, p. 218.
Calocyclas turris Ehrenberg 1876, Pl. 18, fig. 7.
Cycladophora stiligera Ehrenberg 1874, p. 223.
Cycladophora stiligera Ehrenberg 1876, Pl. 18, fig. 3.

Shell with two well-defined strictures. Cephalis hemispherical, poreless, occasionally showing depressions representing infilled pores, bearing a stout, vertical or oblique conical horn which is often roughened or minutely pitted distally. Thorax subspherical, with rough or minutely thorny surface. Thoracic pores circular, hexagonally arranged, usually smaller than intervening bars, hexagonally framed — the corners of the hexagonal frames extended to form the thorns which roughen the thorax surface. Abdomen subcylindrical or slightly flared, narrower than widest part of thorax, with usually 2—5 approximately transverse rows of pores. These usually rectangularly arranged abdominal pores apparently formed by the feet being joined at intervals by usually encircling transverse bars. Often, two adjacent pores of a longitudinal row are fused to form one elongated pore, and occasionally some of the original pores are subdivided by secondary bars to form groups of small rounded pores. Feet usually 11—16, lamellar, sub-parallel or curved inward, tapering to a point (? sometimes originally truncate), their disposition showing no obvious regular relation to the longitudinal rows of thoracic pores. Length of apical horn 40—100 μ, of cephalis 20—30 μ, of thorax 75—120 μ, of abdomen 25—90 μ, of feet 15—110 μ. Greatest breadth of thorax 90—145 μ.

This species differs from all other well-established members of the genus in the nature of the abdomen (sub-cylindrical, with pores basically rectangularly arranged) and feet (broad lamellar, alternating with longitudinal rows of abdominal pores). It is distinguished from *Anthocyrtium hispidum* (Ehrenberg) by the presence of an abdomen. It cannot at present be satisfactorily distinguished from *Cycladophora fenestrata*, *Calocyclas minervae* and *Calocyclas hylogaster* (see discussion, below).

Localities. — Tertiary radiolarian sediment (probably upper Eocene) from »Jeeves oder Boscobelle aus dem Kirchspiel St.

Andrew», »Tank Smith House, Chalky Mount im Scotland District» and one other unspecified locality of the Oceanic formation of Barbados, B. W. I. (EHRENBERG, 1876).

Densinyama and Hagman formations (Eocene), northern and northeast-central Saipan, Mariana Islands (RIEDEL, in press).

Swed. D. S. Exped. Core 77 B, 6.5 cm.; Core 77, 10 and (?) 310 cm.; Core 83, 290 cm.; Core 85 B, 1—39 cm. (sporadically); Core 85, 129—300 cm., 500 cm. and 600 cm.; (?) Core 89, 600 cm.

Discussion. — The above emended description of this species is based on some 40 examples from the upper Eocene part of the Oceanic formation at Bath and Mount Hillaby, Barbados. The species apparently does not extend into the lower Oligocene part of the formation at Bath, and may be completely restricted to the upper Eocene.

The original description of *Cycladophora stiligera* was apparently based on one or more specimens of *Calcyclas turris* with slightly flared abdomen of which the feet had been broken off. In his description of *Calocyclas minervae*, Haeckel (1887, p. 1382) appears to indicate that he realized that *Cycladophora stiligera* has feet, but in another place (1887, p. 1380) he retains this species in its original genus. Most of the uninjured specimens from Bath and Mount Hillaby have lamellar feet tapering to a point, and the original description of the feet as truncate is probably due to the fact that these lamellae are fragile and often broken off at right angles.

It is probable that *Calocyclas turris* is very closely related to, and perhaps derived from, *Anthocyrtium hispidum*, from which it differs mainly in the development of an abdomen by transverse bars joining the feet. *A. hispidum* appears to extend lower in the Eocene than *C. turris*.

Cycladophora fenestrata Haeckel (1887, p. 1380, pl. 68, fig. 2) may be closely allied to, or identical with, *Calocyclas turris*. However, a search through some 23 000 Radiolaria from the sediment at its type locality (»Challenger» Station 265) did not reveal any specimens which could belong to either of these species. The fact that reworked Eocene species are apparently rather common in the sediment at this locality appears to support the supposition that *Calocyclas turris* or a closely related form might be found very rarely in the assemblage.

Calocyclas minervae Haeckel (1887, p. 1382) seems to be a synonym of *C. turris*, but as topotypic material (from »Challenger» Station 332) is not at present available for examination, a decision on this point is suspended. Until this can be determined, the two species may be said to differ in that the thorax of the former species is smooth, and that of the latter rough or thorny — even if this difference is later established as constant, it is doubtful whether such a character should in this group be used to separate taxa at as high a level as species.

Calocyclas hyalogaster Haeckel (1887, p. 1383) may also be synonymous with *C. turris*, but as is the case with *C. minervae*, no topotypic material (from »Challenger» Station 300) is at present available for examination. The abdominal pores of *C. turris* are often separated by wide areas of hyaline shell-wall, and it is possible that Haeckel based the description of *C. hyalogaster* on an individual in which the infilling pores had proceeded further than usual.

Calocyclas virginis Haeckel

Plate 4, figures 3—5; Figure 5

Calocyclas virginis Haeckel 1887, pp. 1381—1382, Pl. 74, fig. 4.

»*Calocyclas* sp.» Jacob and Shrivastava 1952, fig. 2.

Cephalis ovate (usually lobed), with usually irregularly arranged subcircular to circular pores, bearing a three-bladed or (more com-

monly) stout conical horn. Collar stricture pronounced. Thorax subspherical, with smooth or slightly roughened surface. Thoracic pores circular, usually regularly hexagonally arranged, often with a tendency toward apparent longitudinal alignment — ocasionally, longitudinal ribs are developed on surface of thorax, and longitudinal alignment is pronounced. Usually no lumbar stricture, the abdomen being marked off by an internal septal band. Abdomen subcylindrical, often tapering distally, narrower than widest part of thorax. Abdominal pores circular or subcircular, usually smaller than those of thorax, arranged hexagonally with apparent longitudinal alignment (these longitudinal lines continuous with those of thorax), and often with slight longitudinal ribs separating pore rows. Terminal feet usually 12—16, lamellar, usually truncate, parallel, broader than the spaces between them, usually situated opposite alternate rows of abdominal pores.

Length of apical horn 30—180 μ, of cephalis 30—45 μ, of thorax 60—110 μ, of abdomen 10—60 μ, of feet 5—60 μ. Breath of cephalis 25—45 μ, of thorax 80—130 μ, of distal part of abdomen 70—100 μ.

This species differs from *Calocyclas turris* Ehrenberg and *Calocyclas minervae* Haeckel in the arrangement of the abdominal pores (hexagonal pattern, with longitudinal aligment, continuous with pattern on thorax). It appears to differ from *Calocyclas veneris* Haeckel in generally greater number of feet (but see discussion, below).

Localities. — »Challenger» Station 225, N 11° 24′ E 143° 16′; depth 4475 fm. (Haeckel).

Swed. D. S. Exped. Core 73 B, 10—49 cm.; Core 73, 11.5—1471 cm.; Core 76 B, 10 cm. and 20 cm.; Core 76, 208.5—409 cm., 1110 cm. and 1330 cm.; Core 85 B, 1—79.5 cm. (sporadically); Core 85, 30 cm., 299—930 cm.; Core 87, 0—900 cm. (sporadically); Core 89, 300 cm. and 500 cm.; Core 91, 209—1410 cm.

Upper Oligocene or lower Miocene siliceous clays of Colebrooke Island and Ritchie's Archipelago, Andaman Islands (Jacob and Shrivastava; confirmed by the present author as occurring in sediment of the same age from an islet off the NE corner of Colebrooke Island).

Zone 2 (upper Oligocene) of the Cipero formation at Retrench Quarry and Golconda Estate, Trinidad (Riedel, 1954).

Oligocene chalky marl of the sea-cliff along the highway, 1/2 mile SE of the plaza in Jeremie, Haiti.

»Challenger» Station 268 (probably upper Oligocene), N 7° 35′ W 149° 49′; depth 2900 fm. (Riedel, 1954).

Discussion. — The above emended description of the species is based on approximately 50 individuals from the original sediment collected at »Challenger» Station 225, the type locality. Specimens from the other localities mentioned conform with this description, expect that those from Jeremie, Haiti, have usually slightly larger dimensions.

The cephalis is usually peculiarly lobed, as in *Anthocyrtium ehrenbergii* and *Anthocyrtidium cineraria*. In the cephalis of many Archipiliicae, traces of the primary sagittal ring are retained in the wall of the cephalis, and this is occasionally expressed by a slight sagittal constriction which results in the cephalis being weakly bilobed. But in *Calocyclas virginis* it appears that only a part of the primary sagittal ring remains (probably that part which Bütschli considered anterior and Haeckel posterior), and this is accompanied by a corresponding vertical furrow extending part-way up one face of the cephalis (p. s. in Figure 5). Two other furrows, arising opposite one another, extend laterally and downward from this part of the sagittal ring (l. in Figure 5).

It may not be correct to group pronouncedly

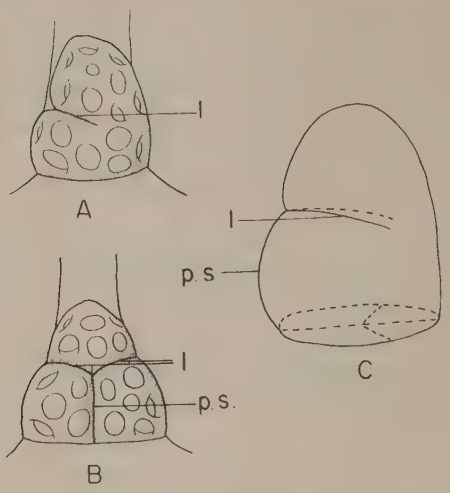

Figure 5. Lobed cephalis of *Calocyclas virginis*. *A* and *B*, sketches of two views (at right angles to one another) showing vertical furrow (p. s.) at primary sagittal ring and two lateral furrows (l.); *C*, diagram showing relation of furrows to the two pairs of basal pores.

costate individuals (Pl. 4, fig. 5) and those in which the thorax shows no longitudinal ridges (Pl. 4, fig. 3) together into one species. However, all transitional stages occur in the assemblages, and therefore no other course of action seems justified. In general, the larger specimens within the range of variation of the species tend more frequently to be costate.

Calocyclas veneris Haeckel may be a synonym of this species. According to HAECKEL (1887, p. 1381), *C. veneris* is cosmopolitan, occurring in the Indian, Atlantic and Pacific Oceans, at the »surface, and in various depths.» The present author, however, has not found any form approximating to HAECKEL's description and figure in any sediments considered to be purely Recent, and is therefore unable to determine what is meant by Haeckel's species. *C. virginis* is present in many Pacific sediments containing reworked middle Tertiary species, and if the two species are synonymous this may account for the description of *C. veneris* as »cosmopolitan».

C. virginis appears to be restricted to the middle Tertiary (Oligocene — ? lower Miocene).

Genus STICHOCORYS HAECKEL, 1882

Stichocorys wolffii Haeckel

Plate 4, figures 6 and 7

Stichocorys wolffii Haeckel 1887, p. 1479, Pl. 80, fig. 10.

Stichocorys baerii Haeckel 1887, pp. 1479—1480, Pl. 80, fig. 8.

Shell with four or more segments (usually 5 or 6), of which the cephalis, thorax and abdomen form an upper conical portion sharply differentiated from the subcylindrical lower portion. Shell surface usually rough or thorny in upper portion, smooth post-abdominally. Cephalis spherical, usually poreless, bearing a sharp conical apical horn of approximately the same length or shorter. Thorax hemispherical, with most of the pores (irregularly or approximately hexagonally arranged) secondarily closed with siliceous lamellae; pores rarely with a tendency toward longitudinal alignment, with rows separated by longitudinal ridges. Abdomen inflated annular, with round pores (sometimes double-contoured) approximately hexagonally arranged, often with apparent longitudinal alignment, of approximately the same width as the intervening bars. Fourth and subsequent segments narrower than widest part of abdomen, thinner-walled than first three segments, with pores of proximal one or two segments often tending to longitudinal alignment with intervening longitudinal ridges, and pores of distal segments irregular in size, shape and arrangement.

Length of first three segments 85—110 μ; breadth of abdomen 65—100 μ, of fourth segment 55—75 μ.

This species differs from others of the genus in the pronounced tendency toward secondary closure of thoracic pores and toward development of longitudinal ridges on the proximal post-abdominal segments. It cannot at present be satisfactorily differentiated from *Stichocorys mülleri* Haeckel (see discussion, below).

Localities. — »Challenger» Station 225, N 11° 24′ E 143° 16′; depth 4475 fm. (Haeckel).

»Challenger» Station 244, N 35° 22′ E 169° 53′; depth 2900 fm. (Haeckel).

Swed. D. S. Exped. Core 73 B, 10—49 cm.; Core 73, 49—1471 cm. (sporadically); Core 76 B, 10 cm. and 20 cm.; Core 76 w. f. 8 cm., 1229 cm. and 1330 cm.; Core 85 B, 1—79.5 cm.; Core 85, 29—300 cm. (?), 399—600 cm., and 700 cm.; Core 87, 0—600 cm. (sporadically); Core 89, 299—(?)600 cm.; Core 91, 210 cm. (?), 309—1410 cm.; Core 93, 300 cm. (?), and 1508 cm.

Zone 2 (upper Oligocene) of the Cipero formation at Retrench Quarry (Riedel, 1954) and Golconda Estate, Trinidad.

»Challenger» Station 268 (probably upper Oligocene), N 7° 35′ W 149° 49′; depth 2900 fm. (Riedel, 1954).

Discussion. — The opinion has previously been expressed (Riedel, 1954, p. 173), that Haeckel's description of this species is insufficient to provide a true picture of its range of variation, and therefore an emended description is now given, based on some 30 well-preserved individuals from the original sediment sample at »Challenger» Station 225 (the type locality). Haeckel's description and figure are apparently based on an extreme variant which is somewhat atypical in the pronounced development of ridges on the thorax, the considerable retention of cephalic pores, and the small number of pores on the fourth segment. The range of variation now established appears to justify the placing of *Stichocorys baerii* as a synonym of *S. wolffii*, although the author has had no opportunity to examine topotypic material of the former species. *Stichocorys mülleri* Haeckel (1887, pp. 1480—1481) may also be a synonym of this species, but it is impossible to establish this on available information. With the object of resolving the question, the author examined a sample of approximately 30 000 Radiolaria from the original sediment sample from »Challenger» Station 268, the type locality of the species. No example conforming with Haeckel's description was found, although *S. wolffii* was common.

In *S. wolffii*, some individuals have double-contoured pores and others have not. Thus in this species and its close relatives, the presence or absence of double-contoured pores is not as reliable a taxonomic character as Haeckel apparently believed it to be.

The small amount of information at present available indicates that this species may be restricted to the middle Tertiary.

Genus EUCYRTIDIUM Ehrenberg, 1847

Eucyrtidium delmontense Campbell and Clark

Eucyrtidium (*Eucyrtis*) *delmontense* Campbell and Clark 1944, p. 56, Pl. 7, figs. 19 and 20.

The author has previously discussed difficulties involved in the taxonomic discrimination between this and several other similar late Tertiary species, and the time-stratigraphic significance of this group (Riedel, 1952, pp. 8—9; 1953, p. 813). It seems advisable, for the present, to restrict the species to include only those agreeing rather closely with the original description, though it appears likely more thorough investigation of Miocene species of *Eucyrtidium* and *Stichocorys* will result in broadening the definition to include species described earlier (e. g., perhaps *Eucyrtidium bütschlii* Haeckel and *Stichocorys saccoi* Vinassa). *Eucyrtidium delmontense* was described originally from the Miocene Valmonte diatomite of Southern California, and may be restricted to the Miocene.

Localities. — Swed. D. S. Exped. Core 73 B, sporadically; Core 73, 847—1471 cm.; Core 76 B, 10 and 20 cm.; Core 76, 7.5 and

608.5—1330 cm.; Core 85 B, sporadically; Core 85, 600 and 700—1050 cm.; Core 87, 0—900 cm.; Core 93, sporadically.

Eucyrtidium elongatum Stöhr subsp. **peregrinum** Riedel

Eucyrtidium elongatum peregrinum Riedel 1953, pp. 812—813, Pl. 85, fig. 2.

This species, previously known only from an apparently very late Tertiary sediment from the island of Rotti, near Timor, appears to be a very useful age-indicator for tropical Pacific sediments. It is found to occur in several western Pacific cores together with *Pterocanium prismatium*, and has not been found in sediments considered on other grounds to be Quaternary in age, nor in assemblages known to be Miocene. Thus its occurrence in considerable numbers probably indicates very late Tertiary, possibly Pliocene. In cores nos. 76 and 85, the superposition of a zone of abundant *E. elongatum peregrinum* directly on a zone of abundant *E. delmontense* suggests that the former species may have been developed directly from the latter.

Localities. — Swed. D. S. Exped. Core 73 B, 10—49 cm.; Core 73, 11.5—1471 cm.; Core 76 B, 10—25.5 cm.; Core 76, 7.5—509.5 cm.; Core 85 B, sporadically; Core 85, 299—930 cm.; Core 87, 0—900 cm.; Core 89, 300 cm.; Core 93, 1508 cm.

Genus EUSYRINGIUM Haeckel, 1882

Eusyringium fistuligerum (Ehrenberg)

Plate 4, figure 8

Eucyrtidium fistuligerum Ehrenberg 1874, p. 229.

Eucyrtidium fistuligerum Ehrenberg 1876, Pl. 9, fig. 3.

Eucyrtidium sipho Ehrenberg 1874, p. 233.

Eucyrtidium sipho Ehrenberg 1876, Pl. 9, fig. 2.

Eusyringium fistuligerum (Ehrenberg). Haeckel 1887, p. 1498.

Eusyringium sipho (Ehrenberg). Haeckel 1887, p. 1497.

Eusyringium macrosiphon Haeckel 1887, p. 1497, Pl. 78, fig. 12.

Shell generally thick-walled, with somewhat rough surface. Cephalis subspherical, usually poreless but with small depressions representing infilled pores, bearing a heavy conical apical spine with minutely pitted and grooved surface. Collar stricture distinct. Thorax hemispherical, with small circular pores usually irregularly arranged. Lumbar stricture not pronounced. Ovate inflated section, comprising the major part of shell, approximately as wide as long, with approximately hexagonally arranged circular pores larger than those of thorax, constricted distally and contined as a long subcylindrical tube. Pores of tubular portion irregularly rounded to circular, unequal in size and irregularly arranged.

Length of apical spine usually 35—80 μ, of cephalis 18—25 μ, of thorax 25—40 μ, of inflated section 80—120 μ, of tubular portion 70—130 μ. Maximum breadth 95—120 μ.

This species is apparently distinguished from *E. conosiphon* Haeckel mainly by the conical form of the apical horn (but see discussion, below).

Localities. — Oceanic formation of Barbados (Ehrenberg).

»Challenger» Station 266, N 11° 7′ W 152° 3′, depth 2750 fm. (Haeckel).

(?) Eocene Hagman formation, northeast-central Saipan, Mariana Islands (Riedel, in press).

Swed. D. S. Exped. Core 73, 950 cm.; Core 76 B, 10 cm. and 20 cm.; Core 77 B, 25 cm.; Core 77, 9 cm. and 109 cm.; Core 83, 1—290 cm.; Core 85 B, 1—79.5 cm.; Core 85, 29—300 cm., 430 cm., 500 cm.; Core 89, 500 cm.; Core 91, 409—1310 cm. (sporadically).

Discussion. — An examination of many specimens of *Eusyringium* from the Eocene part of the Oceanic formation at Bath, Mt. Hillaby, and Hopefield Plantation, Barbados, shows that the common species of this genus in that formation has a range of variation including both *E. fistuligerum* and *E. sipho*. No consistent distinction can be made on the basis of shapes or relative sizes of pores of the different segments, or the thickness of the shell wall. For this reason, the two species are synonymized under the former name.

It also appears necessary to place *E. macrosiphon* in synonymy with *E. fistuligerum*. Several specimens of *Eusyringium* were found by the author in a small part of the original sediment sample from »Challenger» Station 266: these appear to fall within the range of variation of *E. fistuligerum*, and none had such a long siphon as HAECKEL describes for *E. macrosiphon*. It is therefore probable that HAECKEL's description is based on an unusual variant of *E. fistuligerum*, and this is supported by the fact that the sediment from »Challenger» Station 266 contains other species similar to or identical with forms from the upper Eocene of Barbados.

The status of *E. pachysiphon* Haeckel remains doubtful. It apparently bears considerable similarity to *E. fistuligerum*, and in order to make comparisons with the latter species the author examined a small part of the original sediment sample from »Challenger» Station 225, its type locality. No specimen of the genus *Eusyringium* was found, however, in a search through approximately 15 000 Radiolaria. The author has at present no opportunity to examine the sediment from »Challenger» Station 347, the type locality of *E. leptosiphon* Haeckel — this species may be similar to or identical with *E. fistuligerum*.

Finally, with the object of making a detailed comparison between *E. fistuligerum* and *E. conosiphon*, the author searched through some 80 000 Radiolaria from part of the original sediment sample from »Challenger» Station 268, the type locality of the latter species. Only a few fragmentary specimens of *Eusyringium* were found, however, none of which retained the apical spine: the distal part of the skeleton closely resembles that of *E. fistuligerum*, and a closer comparison must await examination of more »Challenger» material.

E. fistuligerum has been found in the Eocene of Barbados and Saipan, and in no older or younger sediments — except in deep-sea localities where reworking of early Tertiary material is suspected. Therefore the species is considered to be restricted to the early Tertiary.

References

ARRHENIUS, G., 1952. Sediment cores from the East Pacific. *Reports of the Swedish Deep-Sea Expedition*, Vol. V, fasc. 1.

BÜTSCHLI, O., 1882. Beiträge zur Kenntnis der Radiolarienskelette, insbesondere der der Cyrtida. *Zeitschr. für Wissensch. Zool.*, Leipzig, Vol. 36, pp. 485–540, pls. 31–33.

CAMPBELL, A. S., 1954. Radiolaria. In Moore, R. C., and Campbell, A. S., *Treatise on Invertebrate Paleontology*, part D, Protista 3, pp. 11–163.

CAMPBELL, A. S., and CLARK, B. L., 1944. Miocene radiolarian faunas from Southern California. *Geol. Soc. America, Spec. Papers*, no. 51, 76 pp., 7 pls.

CLARK, B. L., and CAMPBELL, A. S., 1942. Eocene radiolarian faunas from the Mt. Diablo area, California. *Geol. Soc. America, Spec. Papers*, no. 39, 112 pp., 9 pls.

CLARK, B. L., and CAMPBELL, A. S., 1945. Radiolaria from the Kreyenhagen formation near Los Banos, California. *Geol. Soc. America, Memoir* no. 10, 66 pp., 7 pls.

EHRENBERG, C. G., 1856. *Mikrogeologie*. Leipzig.

EHRENBERG, C. G., 1861 a. Über die organischen und unorganischen Mischungsverhältnisse des Meeresgrundes in 19800 Fuss Tiefe nach Lieut. Brookes Messung. *Monatsber. k. preuss. Akad. Wiss. Berlin*, 1860, pp. 765–774.

Ehrenberg, C. G., 1861 b. Über den Tiefgrund des stillen Oceans zwischen Californien und den Sandwich-Inseln aus bis 15600. Tiefe nach Lieut. Brooke. *Monatsber. k. preuss. Akad. Wiss. Berlin*, 1860, pp. 819—833.

Ehrenberg, C. G., 1872. Mikrogeologische Studien als Zusammenfassung seiner Beobachtungen des kleinsten Lebens der Meeres—Tiefgründe aller Zonen und dessen geologischen Einfluss. *Monatsber. k. preuss. Akad. Wiss. Berlin*, 1872, pp. 265—322.

Ehrenberg, C. G., 1873. Mikrogeologische Studien über das keinste Leben der Meeres—Tiefgründe aller Zonen und dessen geologischen Einfluss. *Abhandl. k. Akad. Wiss. Berlin*, 1872, pp. 131—399, 12 pls., 1 map.

Ehrenberg, C. G., 1874. Grössere Felsproben des Polycystinen—Mergels von Barbados mit weiteren Erläuterungen. *Monatsber. k. preuss. Akad. Wiss. Berlin*, 1873, pp. 213—263.

Ehrenberg, C. G., 1876. Fortsetzung der mikrogeologischen Studien als Gesammt-Uebersicht der mikroskopischen Paläontologie gleichartig analysirter Gebirgsarten der Erde, mit specieller Rücksicht auf den Polycystinen—Mergel von Barbados. *Abhandl. k. preuss. Akad. Wiss. Berlin*, 1875, pp. 1—226, pls. 1—30.

Frizzell, D. L., and Middour, E. S., 1951. Paleocene Radiolaria from southeastern Missouri. *Univ. Missouri School of Mines and Metallurgy, Bull., Tech. Ser.*, no. 77, 41 pp., 3 pls.

Haeckel, E., 1887. Report on the Radiolaria collected by H. M. S. *Challenger* during the years 1873—1876. *Rept. Sci. Results H. M. S.* Challenger, *Zool.*, Vol. 18, clxxxviii + 1803 pp. 140 pls., 1 map.

Jacob, K., and Shrivastava, R. N., 1952. Fossil Radiolaria and Silicoflagellata from the Tertiary clays of Colebrooke Island and the Ritchie's Archipelago, Andaman Islands. *Science and Culture*, Vol. 17, pp. 346—348.

Lucchese, G., 1927. Radiolari miocenici di Salsomaggiore. *Gior. di Geologia Bologna*, Vol. 2, pp. 80—116, pls. 3—8.

Riedel, W. R., 1952. Tertiary Radiolaria in western Pacific sediments. *Göteborgs Kungl. Vetensk.- o. Vitterhets-Samhälles Handl.*, 7 följ., ser B, Vol. 6, no. 3, 22 pp., 2 pls.

Riedel, W. R., 1953. Mesozoic and late Tertiary Radiolaria of Rotti. *Jour. Paleontology*, Vol. 27, no. 6, pp. 805—813, pls. 84—85.

Riedel, W. R., 1954. The age of the sediment collected at *Challenger* (1875) Station 225 and the distribution of *Ethmodiscus rex* (Rattray). *Deep-Sea Research*, Vol. 1, pp. 170—175.

Seguenza, G., 1880. Le formazioni terziare nella provincia di Reggio (Calabria): Formazione Pliocenica. *Atti R. Accad. Lincei*, 1879—1880, ser. 3, Mem. classe sci. fis., mat. e nat., Vol. 6, pp. 168—234.

Stetson, H. C., 1949. The sediments and stratigraphy of the east coast continental margin; Georges Bank to Norfolk Canyon. *Papers in Physical Oceanography and Meteorology, Massachusetts Inst. Technology and Woods Hole Oceanographic Inst.*, Vol. 11, no. 2, 60 pp.

Stohr, E., 1880. Die Radiolarienfauna der Tripoli von Grotte, Provinz Girgenti in Sicilien. *Palaeontographica*, Bd. 26, (3rd Folge, Bd. 2), pp. 69—124, pls. 1—7.

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EXPLANATION OF PLATES

PLATE 1

Fig. 1. *Panarium penultimum* n. sp. Holotype. Swed. D. S. Exped. Core 73, 911.5—912.5 cm. X 380.

Fig. 2. *Tympanidium binoctonum* Haeckel. Swed. D. S. Exped. Core 83, 99—100 cm. X 380.

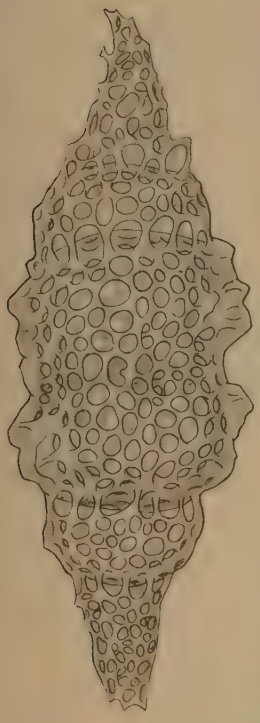
Fig. 3. *Dipodospyris forcipata* Haeckel. Swed. D. S. Exped. Core 83, 99—100 cm. X 175.

Fig. 4. *Dorcadospyris dentata* Haeckel. Swed. D. S. Exped. Core 91, 419—420 cm. X 175.

Fig. 5. *Acrobotrys tritubus* n. sp. Holotype. Swed. D. S. Exped. Core 76, 408.5—409 cm. X 380.

Fig. 6. *Dictyophimus babylonis* Clark and Campbell. Swed. D. S. Exped. Core 83, 99—100 cm. X 380.

Fig. 7. *Sethamphora mongolfieri* (Ehrenberg). Swed. D. S. Exped. Core 85 B, 48.5—49.5 cm. X 380.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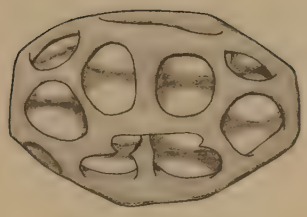
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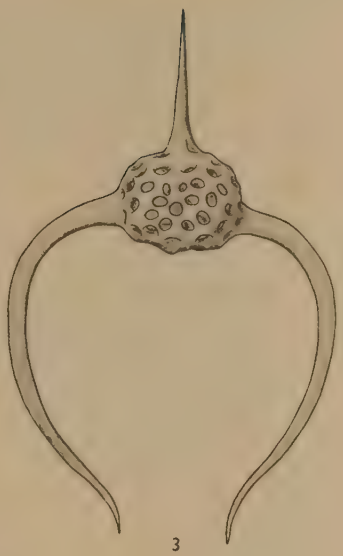
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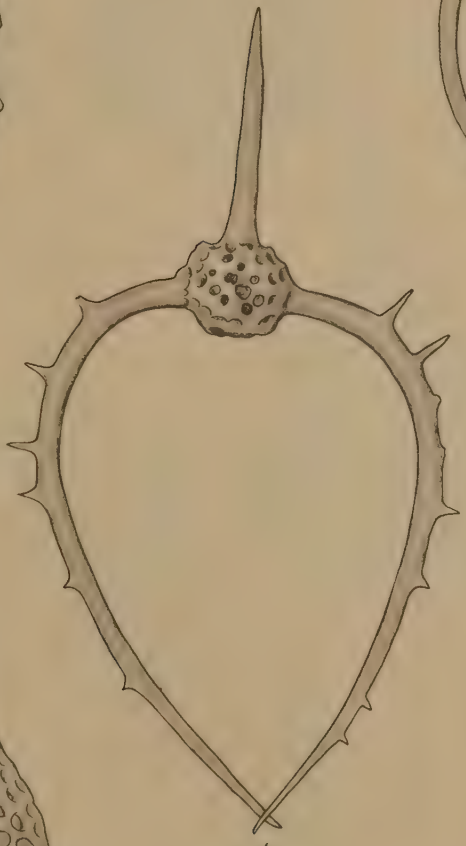
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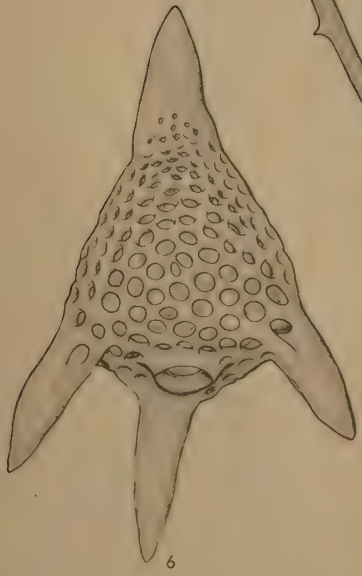
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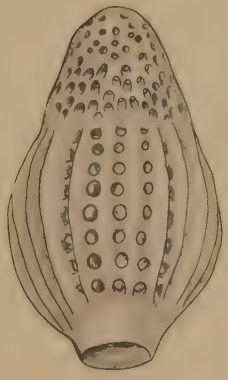
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PLATE 2

Figs. 1—3. *Anthocyrtium ehrenbergii ehrenbergii* (Stöhr). Swed. D. S. Exped. Core 76, 1329—1330 cm. X 380.

Figs. 4, 5. *Anthocyrtium ehrenbergii* (Stöhr) var. *pliocenica* (Seguenza). Swed. D. S. Exped. Core 87, 399—400 cm. X 380.

Figs. 6—9. *Anthocyrtidium cineraria* Haeckel. Swed. D. S. Exped. Core 74 B, 5—5.5 cm. X 380.

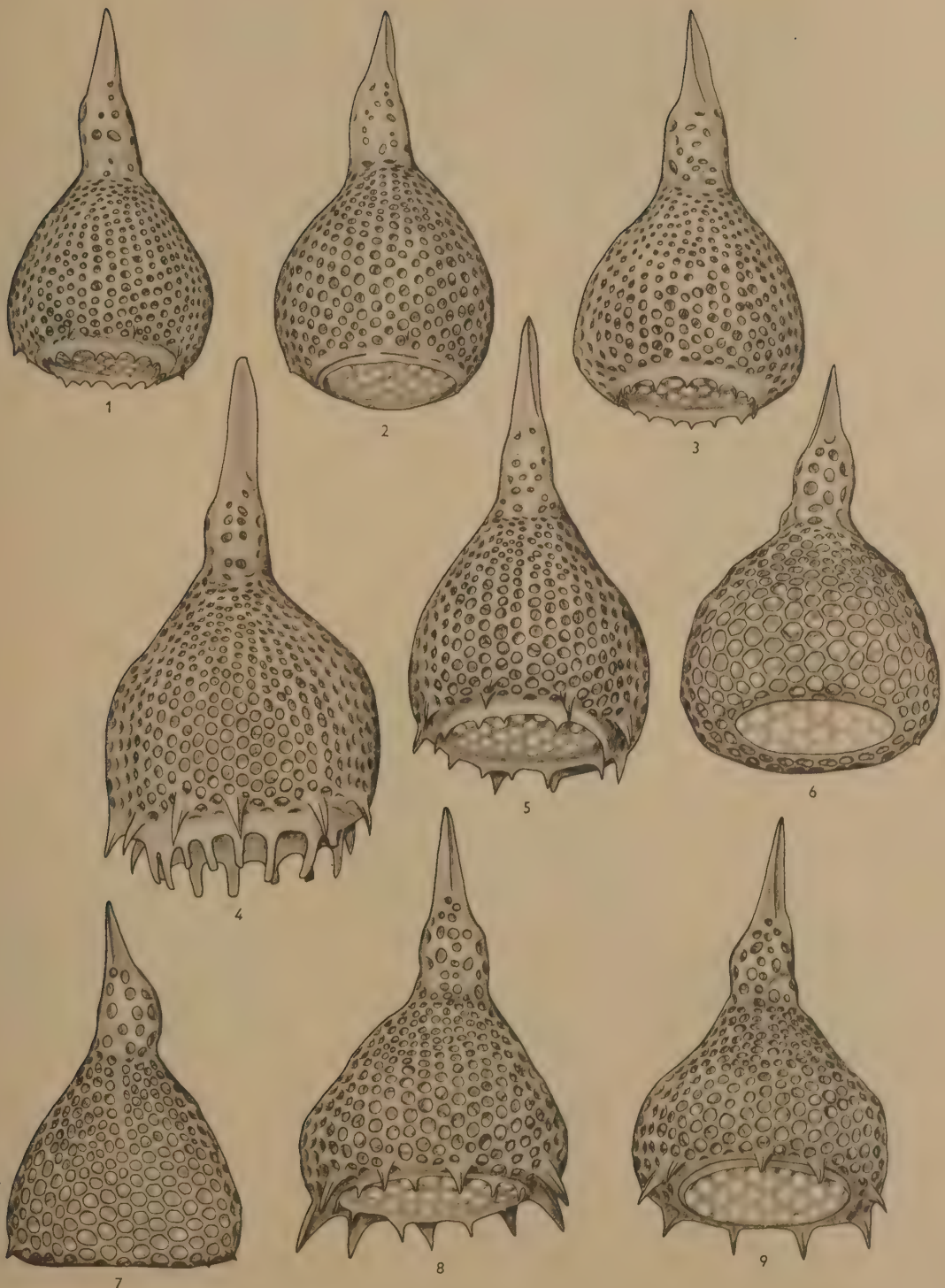
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PLATE 3

Figs. 1—3. *Pterocanium praetextum* (Ehrenberg). Swed. D. S. Exped. Core 74 B, 5—5.5 cm. X 380. 1 and 2, entire specimens; 3, distal portion of an individual with abdominal edge having prominent lobes.

Figs. 4, 5. *Pterocanium prismatium* n. sp. Syntypes. Swed. D. S. Exped. Core 73, 211.5—212.5 cm. X 380.

Figs. 6, 7. *Phormocyrtis embolum* (Ehrenberg). Swed. D. S. Exped. Core 85 B, 48.5—49.5 cm. X 380.

Fig. 8. *Calocyclas turris* Ehrenberg. Upper Eocene part of the Oceanic formation at Bath, Barbados. X 315.

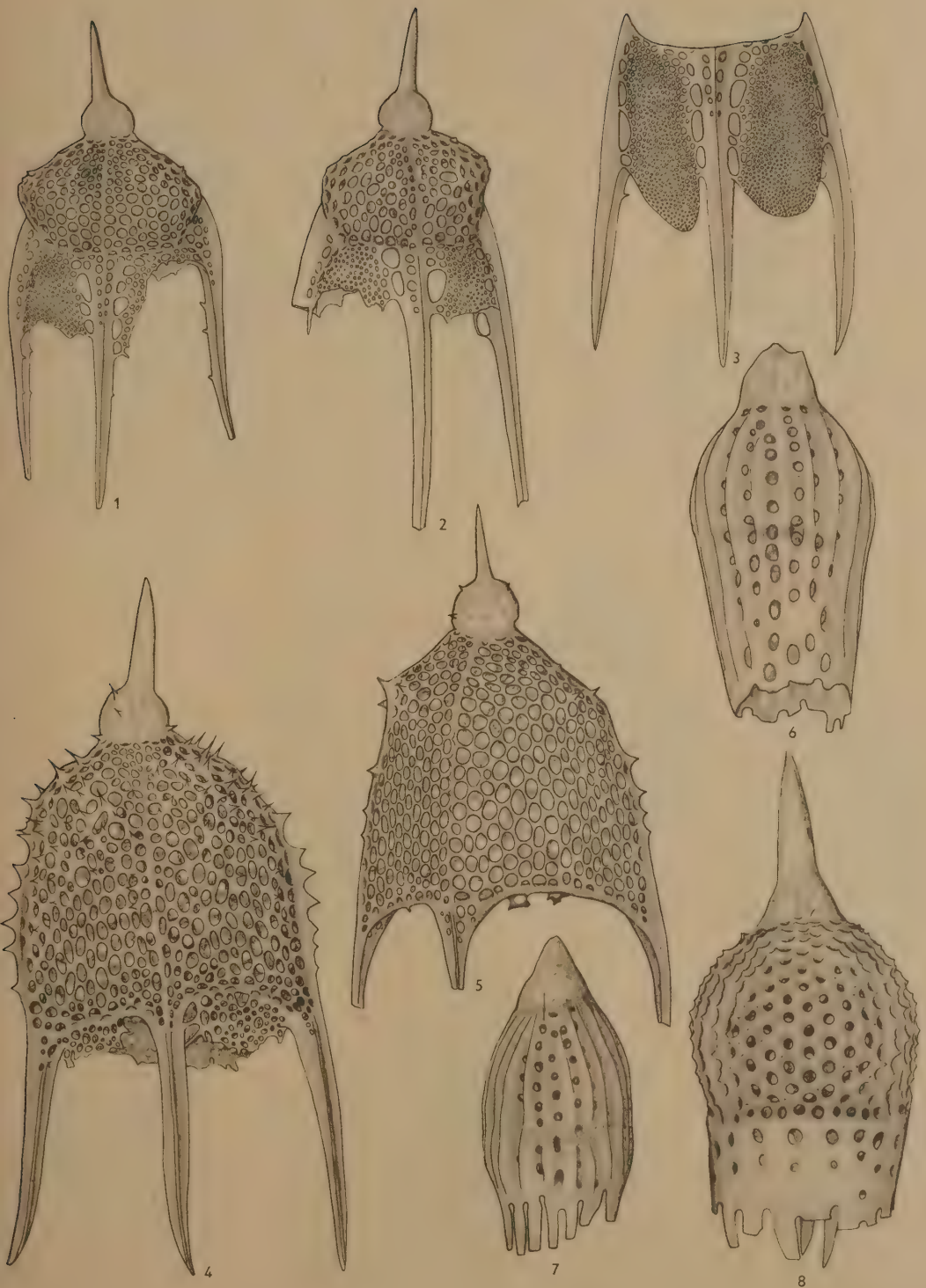
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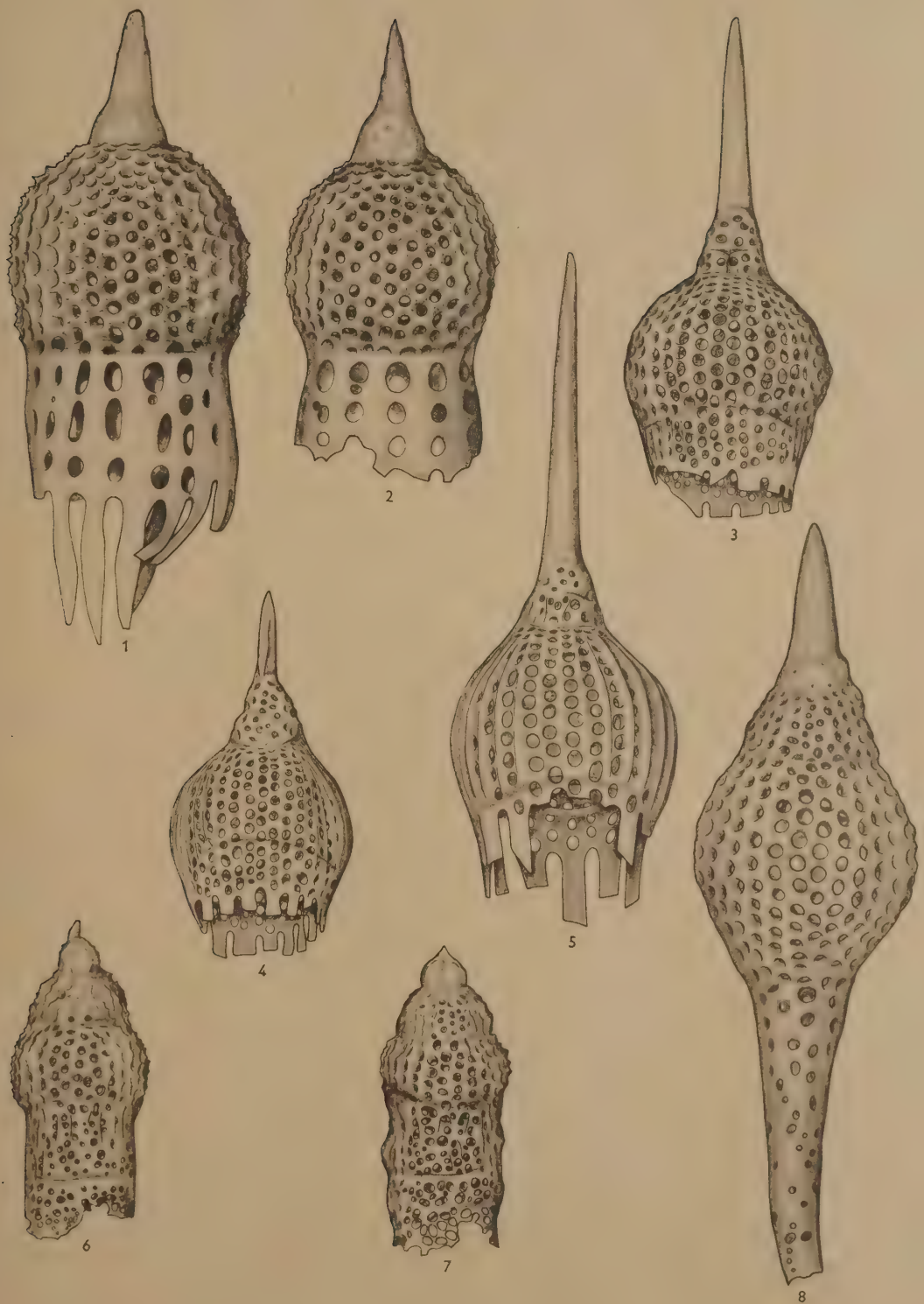
PLATE 4

Figs. 1, 2. *Calocyclas turris* Ehrenberg. Upper Eocene part of the Oceanic formation at Bath, Barbados. X 315. The specimen illustrated in Fig. 2 resembles Ehrenberg's *Cycladophora stiligera*.

Figs. 3—5. *Calocyclas virginis* Haeckel. Sediment from original »Challenger» (1875) Station 225. X 315.

Figs. 6, 7. *Stichocorys wolffii* Haeckel. Sediment from original »Challenger» (1875) Station 225. X 315.

Fig. 8. *Eusyringium fistuligerum* (Ehrenberg). Swed. D. S. Exped. Core 85 B, 48.5—49.5 cm. X 380.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Printed in Sweden
February 1957

GÖTEBORG
ELANDERS BOKTRYCKERI AKTIEBOLAG
1957

PRICE SW. KR. 15:—